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LUTHER BURBANK

HOW PLANTS ARE TRAINED TO WORK FOR MAN

BY LUTHER BURBANK Sc. D

PLANT BREEDING

VOLUME I

EIGHT VOLUMES · ILLUSTRATED

PREFATORY NOTE BY DAVID STARR JORDAN

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LIST OF ILLUSTRATIONS

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A WORD TO THE READER

THERE are two classes of mind, which, when earnestly employed, are rarely combined in the same person; the investigator and the recorder, and when so combined, time becomes the one element lacking. The investigator and the experimenter who is seeking practical results which shall be of lasting benefit to the race, cannot keep verbose records. He must be on the alert in seeking the shortest and best methods which shall lead to the results sought.

These eight volumes are not a compilation from the works or words of others, but a description of some of the

results of actual work for the past fifty years among millions of living plants, including almost every one known to growers and many thousand species never seen in cultivation, which have been discovered by hundreds of my collectors of seeds of wild plants from every part of the earth, most of whom (strangers to me) have sent these seeds in gratitude for the work accomplished here, or in exchange for seeds of my improved plants for the various climates from which the wild seeds came.

All these thousands of varieties are grown and most carefully inspected and selections made for any promise they may give of use for fruit or other food, for flowers, foliage, lumber, fiber, extracts, perfumes or other chemicals, and for combination with our well-known cultivated trees, plants, and flowers, for their improvement.

There is a great amount of literature on the subjects treated in these volumes, and I have a library of more than a thousand books on this and kindred subjects, most of them being theoretical only, or compilations rather than records of actual experimental work.

This work, if carried on extensively, requires constant daily and hourly attention, and these volumes have been mostly written on paper pads during the occasional wakeful hours of night, without light, and of course without use of my eyes, which have always been too much occupied with experiments while daylight lasted. Notwithstanding the fact that those who are making history seldom have time to record it, these records have been made for the benefit of those who follow, and it is hoped that this partial description of actual, vital,

important, productive, and successful work may prove of unusual value to those who have not had any similar fortunate experience, but would be guided in the road to success.

LUTHER BURBANK.

Santa Rosa, California
July 1, 1920

PREFATORY NOTE

LUTHER BURBANK, botanist, naturalist, and plant breeder, son of Samuel W. and Olive (Ross) Burbank, was born in Lancaster, Worcester County, Massachusetts, on March 7, 1849. His ancestry was English-Scotch, the main element being derived from the Puritans who followed the Mayflower Pilgrims from 1625 to 1640. He was educated in the common schools and in a local academy. After a short experience in an agricultural implement manufactory he began market gardening and seed growing in a small way, one of his first and therefore now best known achievements being the development of the Burbank potato from a selected

seedling of the Early Rose. On October 1, 1875, he removed from Massachusetts to Santa Rosa, California, where he has lived ever since, devoting himself to the production of new forms of plants by crossing and selection. He is a member of various learned societies and for some years was lecturer on plant evolution at Stanford University.

Personally Burbank is of medium stature, clear-cut in feature and wiry in physique, a modest, devoted man of science with a keen eye, a deft hand, a broad intelligence, and a sensitive soul. For half a century he has applied himself whole-heartedly to the work of plant improvement. His industry is amazing and almost without parallel; through all these years he has kept thousands of varied experiments going with the mathematical certainty that in the many products of his efforts there would

be some new forms of unusual value. The few gains are positive acquisition. For the sake of one great advance, he can afford to burn thousands of plants of which the combinations of inheritable character show little or no improvement over the parent stocks.

With both animals and plants the general process of creating new forms must of necessity pass through four stages:

1. *Unconscious selection* with more or less isolation of domesticated forms.

2. *Conscious selection of desirable individuals.* By this means, those most available for man's purposes were preserved, and their traits, differing in different regions, became distinctive breed characters. This was the method by which man created his primitive sheep and the wolves he trained (as dogs) to guard them.

3. *Conscious selection toward definite ends.* In this way are formed superior strains within the various species of animals or plants.

4. *Crossing between varieties, races, or species* to increase range of divergence, to add or combine desirable traits, or to eliminate others which may be objectionable. This must be accompanied by isolation to prevent *panmixia* or promiscuous breeding, and also by rigid selection directed to a predetermined definite end. Such a series of processes makes breeding a fine art, one yet in its infancy, no doubt, but in its possibilities the noblest of all arts.

No breeder has any patent on his methods. These are open as the day to all the world and success depends not on tricks but on the brains and skill put into the work. Since the dawn of civilization thousands of men have used these

methods, each in his degree, and thousands will use them again.

Burbank is proud to acknowledge that his success rests on the science of Darwin, who first clarified the laws on which plant breeding must rest. Science is human experience tested and set in order; Darwin brought order into the confused and contradictory observations of thousands of his predecessors. He saw the millions of kinds of living things, not as disconnected entities resulting from specific acts of creation, but as diverging twigs from the great parent tree of life.

The attempt to trace the origin of any species leads one back to the two internal factors, heredity and variation, each in turn checked by external limitations of environment which produce selection and segregation. Of the multitudes of races which spring like suckers from a

vigorous root only those have survived which mastered their surroundings. Adaptations are perpetuated through the nonsurvival of those who failed in adjustment, and separate races are fixed by the natural setting apart—through isolation—of groups of individuals diverging from the parent form.

All these slow processes of nature can be accelerated almost indefinitely through a sympathetic knowledge of plant life in general, and the wise application of this knowledge to the attainment of the special results desired. The experimenter creates his own environment, selecting those individuals which conform, and destroying the others. He then segregates the chosen ones, that their qualities may not be lost in breeding with the mass. The law of heredity, "like produces like," is interwoven inextricably with the law of variation by which no

two organisms, not even two germ cells, are ever quite alike.

Modern studies have given a new meaning to the word ancestor, the bearer of potentialities, and each new individual is a complex of potentialities drawn from different sources. Thus, by selection and consolidation of successful variants, accompanied by separation from the mass, most of the species or kinds of animals and plants we find in nature have been produced.

"Nature," says Burbank, "has time without limit, but man has immediate need for better and still better food, houses and clothing, and our present state of civilization depends largely upon the improvements of plants and animals which have consciously and half-consciously been made by man, and future civilization must more and more depend upon scientific efforts to this end."

By grasping the ways of nature man can plan the end from the beginning. He may and does create species by using nature's methods. Burbank is therefore a "creator"; so is any other man who applies scientific research to the molding of life.

Burbank's experimental gardens at Santa Rosa and on the near-by farm at Sebastopol may be viewed by the biologist as a great laboratory constantly yielding valuable data. Though his immediate purpose is to produce new and improved plants for the benefit of humanity, it is evident that in so doing he works on the borderland of what Darwin called "the problem of problems, the origin of species."

Burbank's ways, then, are nature's ways, in which success comes to the man who follows them most closely. The factors which have made him "dean of

plant breeders'' are the great range of his efforts, the extent of his experiments, his keenness in perceiving slight variations and their meaning, and the rapidity with which he brings results to light by the grafting of seedlings on mature stocks. Dr. Vernon Kellogg* has well said that "the final and most important factor of Burbank's success is the inherent personal genius of the man, his innate sympathy with nature, aided by the practical education in plant biology derived from thirty years of constant study and experiment which enable him to perceive correlations and outcomes of plant growth which seem to have been visible to no other man."

I have called Burbank a botanist because he is one in the highest, the original meaning of the word. But Botany with all her sister sciences has

*Scientific Aspects of Luther Burbank's Works. Popular Science Monthly, October, 1906.

now spread out into a vast realm far too broad for any one man to explore in a lifetime. Burbank's special field is that of plant genetics; here he is artist as well as scientist. Academic, no—but science is not necessarily bred in the academy. Until within the last half century universities fought shy of it, regarding exact knowledge as "materialistic" or even "heretical." Burbank is not a physiologist, still less histologist, and the phenomena of the physical basis of heredity, cell division and cell multiplication, so illumined during the last thirty years, he has not studied in the universities, though his large library contains most of the books which relate to these subjects. In the inheritance of the influence of all environment he shows a faith most botanists of the day have hesitated to share. The extended acceptance of Mendelism and mutation as final words

in species making he very definitely questions. In the application of a knowledge of heredity to the art to which it gives rise in the plant world his supremacy is unchallenged.

I quote again from Burbank: "A knowledge of Mendelism is recognized by me as only the A B C to the broader knowledge of heredity necessary for success in animal and plant improvement, and *all* variations and *all* mutations of every nature are responses to environment which, by repetition and combination, are slowly but surely fixed in heredity and at last made tangible, most often through the crossing of varieties, species, or genera, either by nature or that part of nature called man."

Among other things Burbank has shown that while "sex is not a necessary attribute of all living things," it is "a

most necessary attribute if *progress in evolution of new forms* is to occur, as they have progressed through the ages and as we now see them progressing on this planet." Furthermore, he has insisted that the "power to vary in plants or animals is itself a feature as readily transmissible as is stability of character. The quality of varying to meet varying environments is therefore one of the hereditary traits which the plant breeder must consider, and which may itself be extended or overcome by the processes of crossing and selection.

"It is increasingly necessary (he says) to impress the fact that there are *two distinct* lines in the improvement of any race: the environment which brings individuals up to their best possibilities; the other, ten thousand times more important and effective, selection of the best individuals through a series of genera-

tions." These two lines correspond respectively to Galton's two elements in individual development, "Nurture" and "Nature."

Burbank worked for years alone, not understood nor appreciated, and usually at a financial loss, for his instincts and aims were those of a scientist, not of a horticulturist. To have tried fewer experiments, and those only along lines likely to prove commercially valuable, would have brought him money but not satisfaction. In his way, he belongs to the class of Faraday and the self-taught men of the last generation who dealt steadily with facts, while universities spent their energies on fine points of grammar, and a philosophy which, like an epiphytic plant, had its roots in the air.

My own first realization of Burbank's scientific eminence came from Dr. Hugo de Vries, botanist of the University of

Amsterdam, who, at a dinner in San Francisco in 1904, spoke the following words of eulogy:

"A unique, great genius! To see him was the prime reason of my coming to America. He works to definite ends. He ought to be not only cherished but helped. Unaided he cannot do his best. He should be as well known and as widely appreciated in California as among scientific men in Europe."

Scientists are of many types. Some observe, some compare, some experiment, some deal with general principles, and others carry over knowledge into action. There is need for all kinds and a place for all. With broader opportunities, Burbank could have done a greater variety of things and touched life at more points; but he would thus have lost something of his simple intensity and fine delicacy—things the schools do

not give and too much contact with society sometimes takes away.

Big men are usually of simple, direct sincerity of character. These marks are found in Burbank, sweet, straightforward, unspoiled as a child, devoted to truth, never turning aside to seek fame or money or other personal reward. If his place be outside the great temple of science, not many of the rest of us will be found fit to enter.

DAVID STARR JORDAN.

Stanford University, California
July 5, 1921

FUNDAMENTAL PRINCIPLES OF PLANT BREEDING

ONLY the most limited view of plant breeding can be given in a chapter of ordinary length. It would be necessary to extend the subject through many volumes to give even a general view of what has already been demonstrated, and that which the clear light of science has yet to bring forth from the depths is too extensive even for the imagination to grasp, even through a full knowledge of what practical field work has already accomplished.

The fundamental principles of plant breeding are simple, and may be stated in few words; the practical application of these principles demands the highest and most refined efforts of which the mind of man is capable, and no line of mental effort promises more for the elevation, advancement, prosperity, and happiness of the whole human race.

Every plant, animal, and planet occupies its place in the order of nature by the action of two forces—the inherent constitutional life force

with all its acquired habits, the sum of which is heredity; and the numerous complicated external forces, or environment. To guide the interaction of these two forces, both of which are only different expressions of the one eternal force, is, and must be, the sole object of the breeder, whether of plants or animals.

When we look about us on the plants inhabiting the earth with ourselves and watch any species day by day, or year by year, we are unable to see any change in some of them. During a lifetime, and in some cases, perhaps, including the full breadth of human history, no remarkable change seems to have occurred. And yet there are to-day few, if any, plant species which have not undergone great, and to a certain extent are undergoing, constant change—the invisible changes often appearing abruptly without apparent cause.

The life forces of the plant, in endeavoring to harmonize and adapt the action of its acquired tendencies to its surroundings, may, through many generations, slowly adapt itself to the necessities of existence, yet these same accrued forces may also produce sudden, and to one not acquainted with its past history, most surprising and unaccountable, changes of character. The very existence of the higher orders of plants

which now inhabit the earth has been secured to them only by their power of adaptation to crossings, for, through the variations produced by the combination of numerous tendencies, individuals are produced which are better endowed to meet the prevailing conditions of life. Thus to nature's persistence in crossing do we owe all that earth now produces in man, animals, or plants; and this magnificently stupendous fact may also be safely carried into the domain of chemistry as well, for what is common air and water but nature's earlier efforts in that line, and our nourishing foods but the result of myriad complex chemical affinities of later date?

Natural and artificial crossing and hybridiza tion are without doubt among the principal remote causes of nearly all otherwise perplexing or unaccountable sports and strange modifications, and also of many of the now well-established species. Variations, without immediate antecedent crossing, occur always and everywhere from a combination of past crossings and environments, for potential adaptations often exist through generations without becoming actual, and when we fully grasp these facts there is nothing so very mysterious in the sudden appearance of sports; but still further intelligent crossing produces more immediate results and of

A CROSS OF ORANGE AND LEMON

These curious citrus fruits, which occur spontaneously from time to time, do not appear from immediate crossing of the varieties, but from latent tendencies which appear from former crossings.

great value, not to the plant in its struggle with the ordinary natural forces, but to man, by conserving and guiding its life forces to supply him with food, clothing, and innumerable other luxuries and necessities. Plant life is so common that one rarely stops to think how utterly dependent we are upon the quiet, but magnificently powerful work which is being constantly performed for us.

It was once thought that plants varied within the so-called species but very little, and that true species never varied. We have more lately discovered that no two plants are ever exactly alike, each one having its own individuality, and that new varieties having endowments of priceless value, and even distinct new fixed botanical species can be produced by the plant breeder, often with almost the same precision that machinery for locomotion and other useful purposes are produced by the mechanic.

The evolution and variation of plants are simply the means which they employ, as species, in adjusting themselves to external conditions. Each plant must adapt itself to environment with as little demand upon its forces as possible and still keep up in the race. The best endowed species and individuals win the prize, and by variation as well as persistence. The constantly

varying external forces to which all life is everywhere subjected demand that the inherent internal force shall always be ready to adapt itself or perish.

The combination and interaction of the innumerable forces embraced in heredity and environment have given us all our bewildering species and varieties, none of which ever did or ever will remain always constant, for the inherent life force must be pliable, or outside forces will sooner or later extinguish it. Thus adaptability, as well as perseverance, is one of the prime virtues in plant as in human life.

Plant breeding is the intelligent application of the forces of the human mind in guiding the inherent life forces into useful directions by crossing to make perturbations or variations and new combinations of these forces, and sometimes by radically changing environments, both of which produce somewhat similar results, thus giving a broader field for selection, which again is simply the persistent application of mental force to guide and fix the perturbed life forces in the desired new channels.

Plant breeding is in its earliest infancy. Its possibilities, and even its fundamental principles, are understood but by few; in the past it has been mostly dabbling with tremendous forces,

which have been only partially appreciated, and it has yet to approach the precision which we expect in the handling of steam or electricity, and, notwithstanding the occasional sneers of the ignorant, these silent forces embodied in plant life have yet a part to play in the regeneration of the race which by comparison will dwarf intc insignificance the services which steam and electricity have so far given. Even unconscious or half-conscious plant breeding has been one of the principal forces in the elevation of the race. The chemist and the mechanic have, so to speak, domesticated some of the forces of nature, but the plant breeder is now learning to guide even the creative forces into new and useful channels. This knowledge is a most priceless legacy, making clear the way for some of the greatest benefits which man has ever received from any source by the study of nature.

A general knowledge of the relations and affinities of plants will not be a sufficient equipment for the successful plant breeder. He must be a skillful botanist and biologist, and, having a definite plan, must be able to correctly estimate the action of the two fundamental forces, inherent and external, which he would guide.

The main object of crossing genera, species, or varieties is to combine various individual ten-

THORNLESS BLACKBERRY BLOSSOMS

As to its blossom, the Thornless is a typical and characteristic blackberry. The smooth stem may make one doubt, but on observation of the flower, and later, on viewing the great abundance of its sweet, luscious fruit, its unusual value is very fully appreciated.

dencies, thus producing a state of perturbation or partial antagonism by which these tendencies are, in later generations, dissociated and recombined in new proportions, which gives the breeder a wider field for selection; but this opens a much more difficult one—the selection and fixing of the desired new types from the mass of heterogeneous tendencies produced, for, by crossing, bad traits as well as good are always brought forth. The results now secured by the breeder will be in proportion to the accuracy and intensity of selection and the length of time they are applied. By these means the best of fruits, grains, nuts, and flowers are capable of still further improvements in ways which to the thoughtless often seem unnecessary, irrelevant, or impossible.

When we capture and domesticate the various plants, the life forces are relieved from many of the hardships of an unprotected wild condition and have more leisure, so to speak, or in other words, more surplus force, to be guided by the hand of man under new environments into all the useful and beautiful new forms which are constantly appearing under cultivation, crossing, and selection. Some plants are very much more pliable than others, as the breeder soon learns. Plants having numerous representatives in

various parts of the earth generally possess this adaptability in a much higher degree than the monotypic species, for, having been subjected to great variations of soil, climate, and other influences, their continued existence has been secured only by the inherent habits which adaptation demanded, while the monotypic species, not being able to fit themselves for their surroundings without a too radically expensive change, have continued to exist only under certain special conditions. Thus two important advantages are secured to the breeder who selects from the genera having numerous species—the advantage of natural pliability, and in the numerous species to work upon by combination for still further variations.

Before making combinations we should, with great care, select the individual plants which seem best adapted to our purpose, as by this course many years of experiment and much needless expense will be avoided. The differences in the individuals which we have to work upon are sometimes extremely slight. The ordinary unpracticed person cannot by any possibility discover the exceedingly minute variations in form, size, color, fragrance, precocity, and a thousand other characters which the practiced breeder perceives by a lightninglike glance.

The work is not easy, requiring an exceedingly keen perception of minute differences, great accuracy, and extreme care in treating the organisms operated upon, and even with all the inherent naturally acquired variations added to those secured by scientific crossing and numerous other means, the careful accumulation of slight individual differences through many generations is imperative, after which several generations are often, but not always, necessary to thoroughly "fix" the desired type for all practical purposes.

The above applies to annuals, or those plants generally reproduced by seed each season. The breeder of plants which can be reproduced by division has great advantage, for any valuable individual variation can be multiplied to any extent desired without the extreme care necessary in fixing by linear breeding the one which must be reproduced by seed. But even in breeding perennials the first deviations from the original form are often almost unappreciable to the perception, but by accumulating the most minute differences through many generations the deviation from the original form is often astounding. Thus, by careful and intelligent breeding any valued quality may be made permanent, and valid new species are at times produced by the

art of the breeder, and there is no known limit to the improvement of plants by education, breeding, and selection.

The plant breeder is an explorer into the infinite. He will have "No time to make money," and his castle, the brain, must be clear and alert in throwing aside fossil ideas and rapidly replacing them with living, throbbing thought, followed by action. Then, and not till then, shall he create marvels of beauty and value in new expressions of materialized force, for everything of value must be produced by the intelligent application of the forces of nature which are always awaiting our commands.

The vast possibilities of plant breeding can hardly be estimated. It would not be difficult for one man to breed a new rye, wheat, barley, oat, and rice which would produce one grain more to each head, or a corn which would produce an extra kernel to each ear, another potato to each plant, or an apple, plum, orange, or nut to each tree.

What would be the result? In five staples only, in the United States alone, the inexhaustible forces of nature would produce annually, without effort and without cost, 6,000,000 extra bushels of corn, 15,800,000 extra bushels of wheat, 42,000,000 extra bushels of oats,

2,100,000 extra bushels of barley, 24,000,000 bushels of potatoes.

But these vast possibilities are not alone for one year, or for our own time or race, but are beneficent legacies for every man, woman, and child who shall ever inhabit the earth. And who can estimate the elevating and refining influences and moral value of flowers with all their graceful forms and bewitching shades and combinations of colors and exquisitely varied perfumes? These silent influences are unconsciously felt even by those who do not appreciate them consciously, and thus with better and still better fruits, nuts, grains, and flowers will the earth be transformed, man's thoughts turned from the base, destructive forces into the nobler productive ones which will lift him to higher planes of action toward that happy day when man shall offer his brother man, not bullets and bayonets, but richer grains, better fruits, and fairer flowers.

Cultivation and care may help plants to do better work temporarily, but by selective breeding plants may be brought into existence which will do better work always in all places and for all time. Plants are to be produced which will perform their appointed work better, quicker, and with the utmost precision.

A LARGE, LATE-BEARING RED SEEDLING CHERRY

The cherry here shown (enlarged one-eighth), developed in our colony, differs from the one specifically called the "Burbank" in that it is a very late bearer. The "Burbank" bears particularly early in the season. It is desirable to extend the cherry season, and this variety has been preserved chiefly because of its lateness, although it has many other desirable qualities, as the picture suggests.

Science sees better grains, nuts, fruits, and vegetables all in new forms, sizes, colors, and flavors, with more nutrients and less waste, and with every injurious and poisonous quality eliminated, and with power to resist sun, wind, rain, frost, and destructive fungus and insect pests; fruits without stones, seeds, or spines; better fiber, coffee, tea, spice, rubber, oil, paper and timber trees, and sugar, starch, color, and perfume plants. Every one of these, and ten thousand more, are within the reach of the most ordinary skill in plant breeding.

On scientific plant development now rests one of the next great world movements; the guidance of the creative forces are in our hands.

Man is slowly learning that he, too, may guide the same forces which have been through all the ages performing this beneficent work which he sees everywhere above, beneath, and around him in the vast teeming animal and plant life of the world.

These lines were penned among the heights of the Sierras, while resting on the original foundation material from which this planet was made. Thousands of ages have passed, and it still remains unchanged. In it no fossils or any trace of past organic life are ever found, nor could any exist, for the world-creative heat was

too intense. Among these dizzy heights of rock, ice-cleft, glacier-plowed, and water-worn, we stand face to face with the first and latest pages of world creation, for now we see also tender and beautiful flowers adding grace of form and color to the grisly walls, and far away down the slopes stand the giant trees, oldest of all living things, embracing all of human history; but even their lives are but as a watch tick since the stars first shone on these barren rocks, before the evolutive forces had so gloriously transfigured the face of our planet home.

> *"Some qualities nature carefully fixes and transmits, but some, and those the finer, she exhales with the breath of the individual as too costly to perpetuate. But I notice also that they may become fixed and permanent in any stock, by painting and repainting them on every individual, until at last nature adopts them and bakes them into her porcelain."*—EMERSON.

EVOLUTION AND VARIATION WITH THE FUNDAMENTAL SIGNIFICANCE OF SEX

IN searching for knowledge on any subject it is quite evident that it is best, if possible to start with the foundation facts before attempting to build any useful or beautiful structure, and it will be necessary in this case to repeat some facts available to specialists, but not so generally known or appreciated by others, for upon a knowledge of fundamentals depends the life of any structure.

As a specialist in the study of nature for the definite purpose of producing new forms of plant life, for the better nourishment, housing, and clothing of the race, and the creation of new fragrances and new shades of color in flowers to make life more beautiful, certain very definite conclusions regarding life and its origin on this and probably on other planets have been impressed upon me.

Life is self-expression—a challenge to environment. It is action in certain definite directions

based on mechanical and chemical change. In nature we find varied animate and inanimate forms of life, many of which have motions—some of which in the higher forms we call emotions. These sometimes end in action, at other times in thought.

By common consent we usually associate life as commencing with the unit of life—the individual cell—but life really exists as an organized force in all growing crystals and in a review of the fundamentals of life we must go even to a more primitive form than that of crystal life; below even these we find, instead of the organized growth seen in crystals, an amorphous life. The substances called colloids have no definite structure like crystals, yet they respond to some of the same forces which act upon crystals and upon individual unit cells. These colloidal substances have no very well defined visible structural forms like crystals, yet some of the lowest forms of animal life, like the amœba, are almost as indefinite in form and structure; in fact, having no more definite form than a piece of soft putty or a passing cloud; just a mass of jelly, yet able to perform all the functions and motions necessary to animal life in its primitive state.

Both crystals, the amœba and other unicellular forms, respond definitely to some of the forces

of nature, such as gravity, heat, and light; in other words, have the quality of positive and negative reactions—a limited power of choice; and from such faint prophecies of life, just emerging from the realm of chemistry, have come during aeons of time all the varied plant and animal life on this earth, including man himself.

In a review of the fundamentals of life, we may fairly commence with the crystal forms. Crystals grow when surrounded by a solution which contains abundant nourishment in a temperature adapted to the species, but from the outside, very much like plants and trees in which the nourishing leaf-digested protoplasmic sap flows down, usually in the cambium between the bark and wood, adding thin layers of growth very much after the manner of silver plating, or sedimentation in muddy water.

Crystals, like plants and animals, grow into certain specific forms which may vary to a certain extent to accommodate themselves to their environment, for heredity and environment must be reasonably well fitted to each other, or life always ceases to exist. The internal heredity (formerly acquired) forces and the external or environmental forces must be adapted to meet each other somewhat as a garment fits the body,

not exactly but approximately, and the better the fit the more harmonious the conditions within.

Crystals, like mushrooms, may live and grow without the direct influence of light, while most plants depend wholly upon the action of light for life, and all animal life depends absolutely and wholly for all its nourishment upon the action of sunlight upon the foliage of plants. All food comes first from foliage. The sun feeds the earth from its abundance and by it life is awakened and sustained.

Unicellular plant life was, without any possible doubt, the first form of primitive living organism which appeared on this planet. A cell is an individual entity developed by its environment from more or less amorphous colloidal substances. It is plain that to exist and have an individuality it must be separated from the rest of the cosmos. A cell is, in short, a package of protoplasmic substance inclosed from the rest of the cosmos in its protective covering, large or small, usually very small. Protoplasm, the base of all plant and animal life, is an amorphous compound composed of various chemical substances in a very complicated and unstable form, as is always the case with all vegetable and animal nourishing foods; in other words, it is an

existence separated from the rest of the cosmos, with possibilities of change, for life does not exist except through change; it is always changing, never static, though it sometimes appears to be so in the resting stage, as in seeds, eggs, and the hibernating state of plants, animals, and crystals, all of which appear to be absolutely dead and as lifeless as a brick; but furnish them with their proper nourishing food, in a liquid form with a temperature adapted to the heredity of the species, and observe how quickly they resume growth, even crystals, like plants, under the proper environment, moving out of the resting or dormant stage into the full manifestation of all their attributes.

The cell, being a protoplasmic substance in an envelope—an individual mass of more or less complicated chemical substances in a very unstable condition, separated from the rest of the cosmos surrounding it by a case or wall—has made the first step toward a more complete life. Until such separation, there is little opportunity for any permanent individual change or evolution to occur.

The protoplasm of the amœbic forms of life is compelled to lead a very uncertain existence; the better conservation of life must come from a fuller individuality. This is assured by a skin

of protective envelope separating the individual from the rest of the cosmos, so that it can enjoy individual life and in no other way could this permanently be secured. Even chemicals do not retain their individual character unless inclosed in packages or bottles or cells of some kind, so the cell is a unit of all individual life and it is very evidently necessarily so, in order to meet the obstacles to full development under opposing environment, but it is plain that environmental obstacles can be more readily overcome by a combination of cells. Of course these cell colonies would, in the very nature of the circumstances, be better adapted to survive than single individuals; thus colonies must very naturally have arisen by accretion, producing, during the lapse of ages, all the various forms of vegetable and animal life which the conditions on our planet have now brought and are yet bringing forth. Cell colonies must preserve their very existence by adapting themselves to the aid of all other members of the cell colony—therefore must become specialists in certain directions; thus seed, bark, wood, and leaf cells in plants; and blood, liver, brain, bone, and muscle cells in animal life, though retaining their individuality as modified cells, yet have become, by stress of environment, specialists, for by specialization

only can the functions of a colony be maintained, and upon its integrity depends its continued existence; it must depend upon specialized individuals.

As in multicellular life, so in the structure of our human social fabric individual human life must be specialized to a certain extent so that we may adapt ourselves to existence with one another. Individuals cannot exist except through the mutual aid of one another. The same laws govern cell life, human life, all life. These fundamental laws cannot be evaded. They apply to personal, social, and national life, and any virtue or defect in an individual infallibly affects the whole.

It has been said that a "House divided against itself must fall." A plant, an animal, a man, a society, a nation, a continent or a world whose individual units do not cooperate harmoniously is on the highroad to destruction. All that is precious to the whole human race is devastated by war which threatens to destroy from the earth much that had been built up faithfully and painfully during centuries for the best interests of the race.

The Fundamental Significance of Sex

We find these words in a late scientific work by Dr. L. Doncaster, Fellow of King's College,

Cambridge, England; published by the University Press:

It is a remarkable thing that apart from the fundamental attributes of living matter—assimilation, irritability, growth, and so forth—no single character is so widely distributed as sex; it occurs in some form in every large group of plants and animals from the highest to the lowest and yet of its true nature and meaning we have hardly a suspicion. Other widely distributed characters have obvious functions; of the real function of sex we know nothing, and in rare cases where it seems to have disappeared, the organism thrives to all appearances just as well without it. And in many other cases, especially in plants, where sex is definitely present, it may apparently be almost or quite functionless, as for example, in the considerable number of plants which are habitually grown from grafts or cuttings, and in which the fertile seeds are never set. It is of course impossible to say with confidence that such "asexual" reproduction can go on quite indefinitely, but the evidence formerly adduced that continued vegetative reproduction leads to degeneration has been shown to be of doubtful validity. Sex, therefore, although it is almost universally found, cannot be said with certainty to be a necessary attribute of living things, and its real nature remains an apparently impenetrable mystery.

Now, after more than fifty years of practical experiments in the evolution of new plant forms, the purpose of sex seems too plain even to need much explanation, much less any doubt whatever as to its purpose in the scheme of things.

Sex *is not* a necessary attribute of living things, but it *is* a very necessary attribute if *progress* in the *evolution* of *new forms* is to occur, as they *have* progressed through the past ages and as we now see them progressing on this planet.

We have lately learned that the power to vary in plants and animals is as readily transmissible as stability of character and we also now know that plants and animals brought up for generations under different environments acquire different habits and appearances and, after a time, differences in structure. Each species has had different experiences in adapting itself to its surroundings, and no two individuals of any species, though having similar experiences, have exactly the same. By combination the experiences of both are, by heredity, transmitted either latently or obviously to one or many of their descendants. This combination by crossing, happening again and again, gives added ability to meet and overcome every changing environment; in other words, the power to vary to meet varying environment, and by addition fixing characters which benefit the species through natural selection, giving the new combinations new abilities to advance. Only thus, through combination by sex, has the marvelous variety of plants and animals which now have

ORDINARY FIELD CORN AND ITS TINY PARENT

In the direct-color photograph print shown here a typical ear of "dent" corn is placed for comparison beside the tiny, half wild, teosinte ear which the prehistoric Indians discovered and improved.

a home on this planet, been brought into existence.

The first primitive chemosynthetic half-plant, half-animal life forms without doubt commenced self-expression in and near water, as we also now find them. These lower forms most often multiply by spontaneous breaking to pieces by fission or simple division, and many plants and some animals even, which belong to the higher orders, still retain this power to a certain extent, but no race of either plants or animals ever made any great evolutionary advances until they had adopted a better, more specialized and more economical means. The most ancient races of these early forms very closely resembled those now in existence.

The primitive plan of self-division into equal or many parts, when replaced by the more economical and far more effective one of specialized cells to accomplish the same purpose, also made possible the great variety of life which now exists before us. The change from the old to the new plan was not immediately adopted by all life by any means. Ages passed before the liverworts and ferns appeared, which are among the earlier forms of true plant life. These bear no real seeds, and the specialized cells are dependent upon rains or other *moving water* to carry them

to unite with others to effect a combination of their heredities. Variation must have been almost inconceivably slow before this era of more economical combinations of hereditary acquirements occurred. It is progressing to-day more rapidly than ever since plants and animals appeared on the earth. New varieties, new species, and new genera are all now being produced more rapidly than ever since the sun first gave light to the planet.

The pines and similar plants were developed later. These had employed another great upward step, employing the *wind* to carry the precious package of heredity to another. Most of the forest trees are of this class; they do not vary as do most other flowering trees and plants.

The next step in advance in this direction was when *insects* arrived and by cooperation began carrying the heredity packages of pollen from place to place, for which they received in return a taste of honey. Now comes an era of most astounding development. More than a hundred and forty thousand species were brought into existence and most annual plants and many trees and shrubs and herbs now began, through the selective influence of insects, to produce more conspicuous and fragrant flowers and to secrete honey just in the exact position to induce insects

to search for it, and, in so doing, transfer heredity. No tree or plant that depends permanently and wholly on water or wind to carry heredity has bright colors, fragrance, or a secretion of honey, while *all* which do *depend upon them* have one or all of these for inducement to the insects. Besides all this, each species is adapted to visits of *certain* insects, and most often to *prevent* others. The most wonderful and varied structures in nature are here to be seen. Is this for no purpose or for an unseen one? No! From this fact of *sex* and through its action in combining heredity acquirements, causing infinitely complex combinations, the evolution into a world of a million varied forms has been accomplished. Then why ask the purpose of sex? Is it not self-evident, or why call it an impenetrable mystery?

After having discussed the most vital aspects of the matter, we may now proceed to some very definite conclusions.

Abundant, well-balanced nourishment and thorough culture of plants or animals will always produce good results in holding any species or variety up to its best heredity possibilities, beyond which it cannot carry them, and, lacking which, maximum development can never be realized. But a sharp line must always be drawn between the transient results temporarily

AN EXPERIMENT IN CORN

The ear of corn shown at the left is one which, on an ordinary corn plant, was allowed to take its course, except that one-third of the silk was cut away, leaving a lopsided ear. The other ear is one which was covered with a paper bag at the time when the pollen was falling. The strands of silk thus being protected from pollen, the kernels beneath did not mature. It will be seen from this that the breezes are as necessary to the corn plant as the bees and birds are to the flowers.

attained through favorable environment and the permanent results of *selection of the best individuals* for continuing the race.

What would be the result if *all* apple, plum, corn, melon, or petunia seed was indiscriminately planted? Soon worthless mongrels only, having no character and no value for any purpose.

Only by constant selection of the *best* can any race ever be improved. No education, no environment of any nature can ever make any appreciable progress, even though these same favorable surroundings may produce through ages a definite but infinitely slow increment, which by constant repetition becomes slowly available in heredity, but through many generations by no means fixed, so that reproduction true to the better type can be depended upon.

It is becoming increasingly necessary to impress the fact that there are *two distinct lines* in the improvement of any race; one by favorable environment which brings individuals up to their best possibilities; the other ten thousand times more important and effective—selection of the best individuals through a series of generations. By this means, and by crossing, can any race of plants, animals, or man be permanently or radically improved.

These facts being known, we know how to proceed and, difficult as it may appear, it is the only route by which any permanent advances can, or ever will, be made. When these two lines of action are *combined,* all the best qualities of any type are brought forth and gradually fixed—and the field for improvement is limitless.

HOW PLANTS ADAPT THEMSELVES TO CONDITIONS

The Influence of Environment

IT is the two acres of spineless cactus on one of my experiment farms which first strikes the eye. On the same grounds there are some 3,000 other experiments under way—new flowers, fruits, vegetables, trees, and plants of all descriptions such as man has never before seen, but the velvet-leaved cactus—freed from its thorns—seems more than a plant transformation; it seems to some a miracle.

Every native plant growing on the desert is either bitter, poisonous, or spiny. It was this fact which gave me the suggestion for producing this new plant—a plant which already has shown its ability to outdo alfalfa five to one in quantity and which promises to support our cattle on much land which has heretofore been considered useless, so that our ranges may be turned into gardens to produce the vegetable sustenance for a multiplying population.

ARMORED AGAINST ITS ENEMIES

The spines of a cactus are so arranged as to protect every inch of surface. In addition to the large bristling spines which fan out in every direction, there is hidden behind each rosette a bundle of smaller spines, numbering hundreds to each eye. When the outward spines are removed, these push their way forward with surprising vigor. The form of cactus in the accompanying picture illustrates the fact that away back in history the cactus may have had round stalks instead of flat slabs.

Let us look at the life history of the cactus as it unfolds itself, realizing the importance of the simple fact that desert plants are usually bitter, poisonous, or spiny.

Here are plants which have the hardiness to live, and to thrive, and to perpetuate themselves under conditions in which other useful plants could not thrive.

Here are plants which, although there may not be a drop of rain for a year, two years, or even ten, still contrive to get enough moisture out of the deep soil and out of the air, to build up a structure which, by weight, is 92 per cent water—plants which contrive to absorb from the scorching desert, and to protect from the withering sun, enough moisture to make them nearly as nutritious as beefsteak, watermelons, or pasture grasses.

Here are plants which are veritable wells of water, growing in a land where there are no springs, or brooks, nor even clouds to encourage the hope of a cooling rain; here are plants which are rich in nutriment for man and the domestic animals; here in the desert where the demand for food is most needed—and the supply most scanty.

And here they are, ruined for every useful purpose to man by the spiny armor which places

their store of nutriment and moisture beyond reach.

There is a reason for these spines.

What other reason could there be than that these are nature's provisions for self-defense?

Here is the sagebrush, with a bitterness as irritant almost as the sting of a bee, the euphorbia as poisonous as a snake, the cactus as well armored as a porcupine—and for the same reason that bees have stings, that snakes have fangs that porcupines have arrowlike spines—for self-protection from some enemy which seeks to destroy.

Self-preservation comes before self-sacrifice in plant life as it sometimes does in human life.

The apple, cherry, peach, and plum trees in our orchards bear luscious fruits in abundance; the roses, geraniums, and lilies surrounding our dwellings seem to compete to see which may give us the greatest delight.

But is it not because we have selected, fostered, nurtured, and cared for them?

Is it not because we have made it easy for them to live and to thrive?

Is it not because we have relieved them of the responsibility of defense and reproduction that they have rewarded our kindly care by bloom-

ing and fruiting, not for their own selfish ends, but for us?

We do not cherish the wild cactus or the poisonous euphorbia. We do not cultivate the sagebrush.

Is it, then, to be wondered at that the primal instinct of self-preservation has prevailed—that what might have been a food plant equal to the apple transformed itself into a wild porcupine among plants?

That which might have been as useful to cattle as hay changed its nature and became bitter, woody, inedible.

That which might have been a welcome friend to the weary desert traveler grew instead into a poisonous enemy.

If the bitterness, the poison, and the spines are means of self-defense, then they must be means which have been acquired. These plants were growing here before their habitation became so arid, when animals had an abundance of other food instead of depending entirely upon them; so there must have been a time in their history when they had no need for these various defenses.

How, in sixteen years, I have carried the cactus back ages in its ancestry, proving satisfactorily by planting millions of cactus seeds

that the spiny cactus descended from a smooth-slabbed line of forefathers and how these old characteristics have been not only reestablished but accentuated—all of these things will be explained in due course where the discoveries involved and the working methods employed may be made applicable as well to the improvement of other plants.

It suffices, here, to say that, beginning with this simple observation and reading the history of the cactus from its present-day appearance, I was able to see outlined the method by which a plant yielding rich food and forage and most delicious fruits has been produced, which, as much as any other plant, promises sooner or later to solve the present-day problem of higher living costs.

"But," I have been asked, "do you mean that the cactus foresaw the coming of an enemy which was to destroy it? Is it believable that a plant, like a nation expecting war, could armor itself in advance of the necessity? And if the cactus did not know that an enemy was later to destroy it, would it not have been destroyed by the enemy before it had the opportunity of preparing a means of defense?"

Let us look into the history of the plant and see the answer to these questions.

The facts are that parts of Nevada, Arizona, Utah, and northern Mexico were once a great inland sea—that the deserts now there were the bed of that sea before it began its long process of evaporation.

In these regions, so far as is known, all the North American cacti are supposed to have originated.

Back in the ages before the evaporation of the inland sea was complete, the heat and moisture and the chemical constituents of the sandy soil combined to give many plants an opportunity to thrive. Among these was the cactus, which was an entirely different plant in appearance from the cactus of to-day, no doubt, with well-defined stalks and a multitude of thin leaves like other plants.

As the heat, which had lifted away the inland sea, began to parch the soil, the cactus with the same tendency that is shown by every other plant and every other living thing, began to adapt itself to the changing conditions.

It gradually dropped its leaves in order to prevent too rapid transpiration of the precious life-supporting moisture. It sent its roots deeper and deeper into the damp substratum which the sun had not yet reached. It thickened its stalks

IMPROVED AND WILD CACTI STILL BEAR LEAVES

In the days of the long past and before the animals had begun their work of devastation, the plant had leaves like other plants. That this is so is evidenced by the fact that cactus slabs even now put forth these leaves in rudimentary form, the evidence of an old tendency which has not been entirely obliterated. Shortly after the tiny leaves come out, as shown in this color photograph print, they fall away to be followed by the spines which push out behind them. On all varieties these rudimentary leaves are soft and tender—not spiny.

into broad slabs. It lowered its main source of life and sustenance far beneath the surface of the ground and found it possible thus to persist and to prosper.

Perhaps there were, in the making of the desert, other plants not so adaptable as the cactus, plants which perished and of which man has no knowledge or record.

And so, we may assume, the cactus and those other plants which adapted themselves to the new conditions crowded out those which were unable to fit themselves to survive under these gradually changing conditions.

But there came animals to the bed of this one-time sea, attracted, perhaps, by the cactus and its contemporaries, which offered them food of satisfying flavor and easy access.

Of the plants which had survived the evaporation of the sea and the heat of the broiling sun, there were many, quite likely, which failed to survive the new danger—the onslaught of the animals.

Species by species the vegetation of the desert was thinned out by the elements and by the animals; and the animals, with plant life to feed on, multiplied themselves in ever-increasing hordes, till perhaps the cactus was but one of a hundred plants to survive.

Then came the fight of the cactus to outdo the beasts which sought to devour it—the fight as a family, and the fight within the family to see which of its individuals should be found fit to persist.

Of a million cactus plants eaten to the ground by ravenously hungry antelopes, we will say—antelopes which had increased in numbers year by year while their food supply year by year was relentlessly dwindling—of these million plants gnawed down to the roots, perhaps but a thousand or two had the stamina to throw out new leaves and to try over again.

It is a well known fact that plants which are pliable enough to change their characteristics under changed conditions, more readily adapt themselves to still newer conditions.

As in its previous experience, the cactus had changed the character of its stalk, so now it undertook another change—the acquisition of an armor.

This armor probably at first consisted of nothing but a soft protuberance, a modified fruit bud or leaf, perhaps, ineffectual in warding off the onslaughts of the hungry animals.

So, of the thousand or two left out of the millions, there may have been but a hundred which were able to ward off destruction.

The hundred, stronger than the rest, though eaten to the ground were able still to send up new leaves, and with each new crop the hairs became stiffer and longer, the protuberances harder and more pointed, until finally, if there were even only one surviving representative of the race, there was developed a cactus which was effectually armored against its every animal enemy.

One such surviving cactus, as transformed throughout ages of time, meeting new conditions with changes so slight perhaps as to be almost imperceptible, but gradually accommodating itself to the conditions under which it lived and grew—one such survivor out of all the billions of cactus plants that have ever grown would have been sufficient to have covered the deserts of America with its progeny—to have produced all of the thorny cacti which we have on earth to-day.

The cactus did not prepare in advance to meet an enemy—it simply adapted itself gradually to changing environment as all vegetable and animal life on the earth must—or perish. First, surviving the desert drought and the broiling sun, it threw its roots deep into the earth for the scanty moisture. Then, attacked by enemies which ate off the leaves, it still had life and resistance to try again. Ineffectually, at first, it began to build its armor, but each discourage-

CONTRASTING TYPES OF CACTUS

At the left, a colony of the spineless cactus called the "Tapuna"; at the right a quite different type called the "Tuna." Like all my spineless cactuses, these are crossbred seedlings; and they are of closely similar lineage, notwithstanding their widely different appearance. An instance of the segregation of hereditary characters.

ment proved but the incentive to another attempt. It is a vivid picture; the whole cactus family in a death struggle for supremacy over enemies which threaten its very existence — millions and millions of the family perishing in the struggle, and perhaps but one victorious survivor left to start a new and armored race.

It is wonderful, but whenever we plant a cactus slab to-day we see evidences of adaptability even more wonderful than this.

The slab of cactus is an olive green color as we put it in the ground. It is flat, of an oval shape, an inch or less in thickness. Its internal structure is of a soft juicy texture—like most succulent vegetables largely water.

As the slab sends down roots, it begins to prepare itself to bear the burden of the other slabs which are to grow above it.

The thin, flat shape thickens out until it is almost spherical; thus presenting a curved surface in four directions instead of in two, it braces itself against the winds which will endanger the tender new slabs far above it.

Its tender woody fibers grow tough and resistant; it loses its velvety skin and develops a bark like that of a tree.

Within a year after planting, this cactus slab will have changed in appearance and in char-

acteristics to fit itself to the new conditions which surround it.

It will have changed its structure to bear weight and stand strains. It will have modified its internal mechanism to transmit moisture instead of to store it. It will have remodeled its outer skin to protect itself from the ground animals from which it had no reason to fear destruction while growing higher up on the parent plant.

Is it more wonderful that, unseen by us, a plant should have adapted itself to the desert and, through the ages, have armored itself against an enemy, than that, before our eyes, in a single year, it should meet changed conditions in an equally effective way?

Is it more wonderful that it should grow spines than it should grow slabs which in turn have the power to grow other slabs?

Is not the really wonderful thing the fact that it grows at all?

The cactus is one of the most plastic of plants —educated up to this, perhaps, by the hardships and battles through which its ancestry has fought its way.

A slip cut from a rosebush, for example, must be planted in carefully prepared ground of a suitable kind, at a certain season of the year,

with regard to moisture and temperature—it must be watched and cared for until it takes root and is able to care for itself. The rose has evidently not had as severe a struggle as the cactus.

But the cactus, having developed itself under the most discouraging conditions needs no such care. Every one of the fifty or more wartlike eyes on its every slab is competent to throw out a root, a fruit, or another slab—whichever the occasion seems to warrant.

Lay a cactus slab on hard ground, unscratched by a hoe, and the eyes of its under side will throw long white roots downward, while the eyes on the upper side await their opportunity, once the slab is rooted, to throw other slabs and blossoms upward.

As the tiny buds grow from the eyes, it is impossible by sight or microscopic examination to determine which will be roots, which will be fruits, or which will be other slabs. It is as though the cactus, inured by hardship and prepared for any emergency, waits until the very last possible moment to settle upon the best-suited means of reproduction—as though the bud, having started, becomes a root if it finds encouragement for roots, or a fruit if seed seems desirable, or an upward slab if this can be supported.

Nor does its attempt at reproduction require much encouragement. Fifty young cactus slabs laid on a burlap-covered wooden shelf four feet above ground were found to have thrown long roots down through the burlap and through the cracks of the boards within a few days.

A cactus plant pulled from the ground and tied by a string to the branch of a tree remained hanging in the air for six years and eight months. During this time it had no source of nourishment and its slabs shriveled and turned a light brown. By planting these slabs in the ground they immediately took root and within a few weeks began to throw out buds and new slabs.

A detached cactus slab, long forgotten in a closet, after having been in the dark for more than two years, was found to have thrown out a sickly looking baby slab.

The more the adaptability of the present-day cactus and its tenacious hold on life are observed, the easier it becomes to understand its successful fight against its numerous enemies which lived during the desert-forming age, and to see the origin of the thorny cactus of to-day.

Nor is the cactus the only desert plant which shows evidences of such a struggle.

The goldenrods of the desert are more bitter than the goldenrods of the plains.

The wormwood of the desert is more bitter even than the wormwood which grows where there have been fewer enemies.

The yuccas, the aloes, the euphorbias, all have counterparts in their families, which, needing less protection, show less bitterness, less poison, fewer spines.

And even rare cactus plants from protected localities, and those of the less edible varieties, give evidence, by the fewness of their spines, that their family struggle has been less intense than the struggle of the cactus which found itself stranded in the bed of a former inland sea.

Plants which have shown even greater adaptive powers than the cactus are to be found in the well-known algæ family.

One branch of this family furnishes an apt illustration of the scant nourishment to which a plant may adapt itself.

Microscopic in size, it lives its life on the upper crust of the Arctic snow storing up enough energy in the summer, when the sun's rays liquefy a thin film of water on the icy surface, to sustain life in a dormant stage during the northern winter's six months of night.

With nothing but the moisture yielded from the snow, and what nutriment it can gather from the air, this plant, called the red snow plant,

VESTIGIAL LEAVES

The projections here shown on one of the older slabs are vestigial leaves. An account of them, with reference to their evolutionary meaning, is given in this volume. They are all that remain of the leaves that the cactus once bore; and these reminiscent leaves drop off very shortly after coming out, leaving my new varieties as smooth as velvet.

multiplies and prospers to the extent that it covers whole hillsides of snow like a blanket—covers them so completely that the reddish color of the plant, imparted to the snow, first gave rise to the tales of far northern travelers as to the color of the snowfall and explained the apparent phenomenon of red snow.

Another division of this family, at the opposite extreme, thrives in the waters of Arrowhead Sulphur Springs in California—lives its life and reproduces itself in water so hot that eggs may be easily cooked in it.

In addition to these microscopic members, one thriving on the Arctic snows, the other in water at nearly the boiling point, there is still another member of this family which has formed the largest plant colony in the world. This, the gigantic growth of the Sargasso Sea, consists of a small seaweed wrenched from the coast and forms a huge tangled, floating mass.

And so on; some of this family of the algæ grow on and in animals, some on other plants, some on iron, some on dry rocks, some in fresh water, and some in the salt seas.

The monkey-puzzle trees, Araucarias, show an adaptability to environment as striking as that of the cactus—although for a wholly different purpose.

At the top of this monkey-puzzle tree, so called, are borne several very large cones containing the large nutlike seeds of the tree.

In the case of the cactus the thorns were developed to protect the plant itself from destruction but in the case of the monkey-puzzle tree the animals threatened not the tree itself, but its offspring—its nuts were so highly prized by the monkeys, and their number was so few, that it was forced to take protective measures to keep its seed out of the reach of enemies.

From this we begin to see that each plant has its own family individuality, its own family personality. Some plants, in order to insure reproduction, produce hundreds or thousands of seeds, relying on the fact that in an oversupply a few will likely be saved and germinated; while other plants producing only a few seeds protect them with hard shells or bitter coverings, or, as in the case of the monkey-puzzle tree, with sharp spines at the tip of every leaf and all over the branches.

In the deep canyons of California's mountains there grows a member of the lily family, the trillium.

Near the bottom of these canyons there are places where the sunshine strikes but one side. The flowers on the shady side of the canyons are larger, and the leaves of the plants are broader,

and the bulbs are smaller and nearer the surface than those of the plants which grow where the sun reaches them.

On the other side of the same canyons the bulbs grow larger and deep in the soil, and the leaves and the blossoms transform themselves to conserve moisture.

Which was all that the cactus did when the sea was turned into a desert.

About the geysers of Sonoma County, and scattered over other arid portions of California, Arizona, and Mexico, there are a group of pines (*Pinus tuberculata, muricata, attenuata, chihuahuana*) having most remarkable characteristics, evidently having been subjected in long ages past to frequent fires, probably often started by the fires of this and other volcanic regions. The ground in the vicinity of the locality chosen by these pines is sometimes even yet so hot that it is difficult to walk over it, even with heavy boots, without burning the feet. There must have been a time, as all the evidence shows, when fires were quite common from volcanic action, and these pines have learned a lesson which no other pines or other coniferous trees on this earth have had to learn.

The cones of most pines take two years in which to mature the seed, and all other pines open once

A BEAUTIFUL FLOWERING CACTUS

This is the cactus known as Opuntia basilaris, a low-spreading form that makes a very striking contrast with the giant spineless opuntias. The present species is too small to be of any value as a forage plant, but its flowers give it high rank as a border plant for the garden. The color of the flower is far more brilliant than the picture.

each two years at the proper season to distribute their seeds. The seeds of other pines do not retain their vitality and ability to grow even after the third year. The Geyser pines produce cones in great abundance in circles around the trunk and branches when much younger than other pines—sometimes when only two or three feet in height. The cones of these pines remain closed on the trees so persistently that the new wood sometimes grows over them, surrounding them completely, but the seeds, even in these cases, remain in best growing condition after their long imprisonment in the wood. The cones never open to distribute the seed until a fire sweeps over the land, when those which have been gathering on the trees, perhaps for thirty or forty years, immediately open and soon after scatter the seed, from which the young pines often come up as thick as grass on a lawn. Of course some of these succumb to the crowding of their neighbors, but what a wonderful adaptability these pines have shown; a lesson which no other pine has been obliged to learn. In learning these hard lessons which have become so deeply fixed in heredity, innumerable individuals have taken part, for time is generally the chief factor, and they can be fixed only by repetition.

Let the cactus, battle-scarred and inured to hardship, teach us our first great lesson in plant improvement:

That our plants are what they are because of environment; that simply by observing their structures, their tendencies, their habits, their individual peculiarities, we can read their histories back ages and ages before there were men and animals—read it, almost, as an open book; that our plants have lived their lives not by quiet rote and rule, but in a turmoil of emergency; and, just as they have always changed with their surroundings, so now, day by day, they continue to change to fit themselves to new environments; and that we, to bring forth new characteristics in them, to transform them to meet our ideals, have but to surround them with new environments—not at haphazard, but along the lines of our definite desires.

It is far more wonderful even that plants grow at all than that they can so readily adapt themselves to changing conditions.

TWENTY-THREE POTATO SEEDS AND WHAT THEY TAUGHT

A Glimpse at the Influence of Heredity

THE springtime buds unfold into leaves before our eyes—without our seeing them unfold. We have grown accustomed to look for bare limbs in March; to find them hidden by heavy foliage in May; and because the process is slow, and because it goes on always, everywhere about us, we are apt to count it commonplace.

Just as we can understand that the tree in our yard, responding to its environment—to the April showers, to the warm noons of May, to the heat of summer and to the final chill of fall—has completed a transformation in a year, so, too, can we more easily understand the gradual transformation of the cactus in an age. We can also realize that the individual steps between the first ineffectual hairy protuberance, and the final

spiny armor, each a stronger attempt to respond to environment, were perhaps so gradual as to be imperceptible.

But those rudimentary, half-formed leaves which come forth from every eye of the cactus slab before the thorns or fruits come out—those leaves which, no longer serving any useful purpose, soon turn yellow, die, and fall off—which environment has acted to reject though once of fundamental importance to the plant?

And those two smooth slabs that push out when the tiny seedling has just poked its thorny head above the ground—why should they be smooth while the first central leaf is thorny?

How shall we account for this tendency in a plant to jump out of its own surroundings, and out of the surroundings of its parents, and their parents and those before them—and to respond to the influences which surround an extinct ancestor—to hark back to the days when the desert was the moist bottom of an evaporating sea and before the animals came to destroy?

A group of scientists were chatting with me once when a chance remark on heredity led one of them to tell this bear story:

It seems that a baby bear had been picked up by miners within a few days after its birth—before its eyes had opened. The cub, in fact, was

so small that it was carried several miles to the camp tied in the sleeve of the coat of one of the miners.

Raised to adult bearhood by these miners, without ever having seen another bear—relieved of the necessity of finding its own food and removed from the wild environment of its ancestors —this bear had become as thoroughly domesticated, almost, as a tabby cat.

What would such a bear do if thrown on its own resources? Would it have to begin at the beginning to learn bear-lore?

Bears are great salmon fishers, for example.

But is this skill taught by the mother to the baby bear—or is it a part of every bear at birth? That was the question of interest.

When the animal had arrived at maturity, it was taken, one day, to a shallow salmon stream.

Here was a bear which had never fished for salmon, and had never tasted fish; a bear which, if bears have a language, had not received a moment of instruction in self-support; a bear which, taken before its eyes were open, had never seen its mother, had never known an influence outside of the artificial atmosphere of the mining camp.

Brought to the salmon stream, however, there was not an instant of delay; it glanced about,

located a natural point of vantage, straddled the brook with its face downstream, and bending over, with upraised right paw, waited for the salmon to come.

It did, unhesitatingly, just what any normal wild-raised bear would have done.

With wonderful dexterity it was able to scoop the onrushing salmon out of the stream and to throw them in an even pile on the bank with a single motion.

As other bears would do, this domesticated bruin stood over the stream until it had accumulated a considerable pile of the salmon on the bank.

Going to this pile it quickly sorted over the fish, making now two piles instead of one—*with all the male salmon in one pile and all the female salmon in the other.*

Then, with its sharp claw, it proceeded to split open the female salmon and to extract the roe, which it ate with relish. This consumed, it finished its meal on the other meat of the fish.

Untaught, it recognized salmon as food; distinguished males from females; knew the roe as a special delicacy. Unpracticed, it knew, instantly, just how to fish for salmon and how to find the roe.

Right here on this experiment farm you may find hundreds of evidences of heredity more striking than that—more striking because they are the evidences of heredity in plant life, instead of in animal life.

Here you will find plants which show tendencies unquestionably inherited from a line of ancestry going back perhaps ten thousand years or more—tendencies, some of them, which now seem strangely out of place because the conditions which gave rise to them in their ancestors no longer exist; tendencies like those of the cactus, the rose, and the blackberry to protect themselves from wild beasts when wild beasts are no longer enemies; tendencies to deck themselves in colors designed to attract the insects of a forgotten age—insects which, perhaps, no man has ever seen.

Where some incredulity might be expressed as to whether the bear had not actually been taught to fish for salmon, or seen another bear perform the act, there can be no such question in the case of heredity in plants.

Here in this bed of sweet peas is a plant which has inherited the climbing, twining tendency.

This is an evidence that, at some time back in its history, this plant has probably been crowded for room. Plants which grow high do so usually

because, at some stage in their existence, they have had to grow high to get the sun and air which they need. Low-lying plants, like the pumpkin for example, give evidence that they have always enjoyed plenty of space in which to spread out.

It might be thought that the bear in the story may possibly have slipped away, unknown to its keepers, and seen another bear fish for salmon; but if these tendencies and traits, and if the ability to perform the feats necessary for existence are not passed down from mother to son—if they do not come down through the line of ancestry, if all of the old environments of the past have not accumulated into transmissible heredity, what enables that sweet pea to climb upon some support to reach the needed light?

A closer observation of the sweet pea will show us that its tendrils are really modified leaves, produced like the spines of the cactus, by ages of environment which, added up, combine to make heredity; and that their actual sensitiveness to touch is so highly developed that they adroitly encircle and hold fast to any suitable support within their reach.

It would be interesting to take a motion picture of the sweet pea as it grows, as similar

motion pictures have been taken; making separate exposures, one every three minutes instead of fifteen or sixteen to the second, so that the reel would cover a period of fifteen days; then, with a fifteen-day history recorded on the film, to run it through the projecting lantern at the rate of fifteen or sixteen pictures to the second, thus showing in seven or eight minutes the motions of growth which actually took fifteen days to accomplish; on the screen before us, with quick darting motions, we should see the sweet pea wriggle and writhe and squirm—we should see it wave its tendrils around in the air, feeling out every inch within its reach for possible supports on which to twine.

We should see, by condensing half a month of its life into an eight-minute reel, that this sweet pea has inherited an actual intelligence—slow in its operation, but positive, certain—an inherited intelligence which would be surprising even in an animal.

Throughout all plant life we find these undeniable evidences of environment having affected heredity.

Here, for example, are two tiny seedlings which look almost alike. They are distinctly related. One is the acacia (*A. mollissima*) and the other the sensitive plant (*Mimosa pudica*).

Much as these plants look alike, they bear witness to the fact that they have within them two entirely different strains of heredity.

The acacia will permit us to touch it and handle it without showing signs of disturbance.

But its cousin in the same soil, and of the same size, immediately folds up its leaves, in self-protection, at the slightest touch.

From this we read the fact that one branch of this family has found it necessary to perfect a form of self-defense, while the other has had no such experience in its life history.

The acacia being a tree which grows out of the reach of browsing animals, while the sensitive plant is a low-growing succulent tender plant, the acacia needs no thorns, and has none, while the sensitive plant has the added defense of numerous thorns.

I have been much interested lately in an experiment with clover—in producing clover leaves with wonderful markings.

The only way in which I can account for the markings with which some clover leaves will bedeck themselves is that, in the heredity of the plant, there was a time when, not being poisonous itself, it tried to simulate the appearance of some poisonous plant to protect itself from insects or other enemies.

At first thought it might require a stretch of the imagination to understand how this could be —yet a closer inquiry shows that the process was as gradual and as surely progressive as the transformation of the cactus.

In clover, as with all other plants, there has always been variation—some few individuals have always had the white and black markings.

At some time in the history of the plant those without the markings may have been destroyed, and so, responding to this new environment, the markings became more and more pronounced until now we have not only white triangular markings, but deep black splotches and red and yellow colors intermixed in curious figures.

From these markings we can readily imagine the history of this Chilean clover—most of the family having plain leaves inherited from an ancestry which found no need to protect itself from an enemy—with an occasional outcropping of poisonous-looking color splotches—the inheritance of environments in which self-protection was necessary.

Or we might consider the ice plant (*Mesembryanthemum crystallinum*) which protects itself from the heat and evaporation of the sun by surrounding itself with tiny water droplets which have the appearance of ice; or the wild lettuce,

known sometimes as the compass plant, which turns its leaves north and south so that only their edges are reached by the sun; or any of a number of other strange protective measures which plants have perfected—all manifestations which would be impossible if heredity were not an ever-present, controlling influence.

We have, too, in many parts of the country, plants which have learned to snare and trap insects and even small animals and with a secretion somewhat resembling gastric juice to digest them and from them obtain an added supply of nourishment.

Among these carnivorous plants are the common pitcher plants.

The pitcher plants, instead of belonging to only one species, are to be found having this habit developed in several species, thus showing that environment has produced a similar strain of heredity in the several species.

One of the pitcher plants (*Darlingtonia californica*) which grows abundantly in the moist meadows of the Sierras in northern California even catches frogs, mice, and other small animals, and sometimes even birds. The plant is especially equipped to lure its prey into its pitchers. Above the pitcher is a little latticed window, through which the light can shine. The insects and the

animals see a haven from the sun and rain, and as they go in, there are long sharp little fingers all pointing inward and downward, under the latticed window, just right to hasten and project its prey into the pool of water inside the pitcher, prepared for this very purpose.

In these traps it is common to find all kinds of insects—including the undigested wings and legs of beetles and grasshoppers, and sometimes the bones of toads and frogs.

Is this not a more wonderful manifestation of odd environment, recorded within a plant in the form of heredity, than even that of the bear which seemed to have inherited the intelligence and skill to fish?

"To my mind," said one of the scientists, "the by-product of your work is fully as interesting as the work itself—the viewpoint which you get on the forces which control life is of even greater attraction to me than the wonderful and useful productions which you have coaxed from the soil."

But hardly a by-product, for these things are a vital part of the day's work. Heredity is more a factor in plant improvement than hoes or rakes; a knowledge of the battle of the tendencies within a plant is the very basis of all plant improvement. It is not, as one might think, that

THIS PLANT EATS AND DIGESTS INSECTS

The pitcher plant (Darlingtonia) shown here, which grows in the high mountains of California, has perfected an ingenious contrivance for catching and digesting insects. At the top of the pitcher, so called, seen above, there is an opaque lattice work in the interstices of which is a translucent, micalike substance. The insect, entering from beneath in search of shelter, finds itself in a cosy chamber, well lined and weatherproof. Once inside the chamber, however, it discovers that it is being swallowed, irresistibly, and the plant finally deposits it in the stomach below, where it digests it with a secretion akin to hydrochloric acid. There are several other known carnivorous plants, showing that at some time in their ancestry the soil has not given them sufficient nutriment for their needs.

the work of plant improvement brings with it, incidentally, a knowledge of these forces. It is the knowledge of these forces, rather, which makes plant improvement possible.

There are really, after all, only two main influences which we need to direct, in order to change and control the characteristics of any individual growing thing.

The first of these is environment.

Rains, snows, fogs, droughts, heat, cold, winds, the change in temperature between night and day—soil, the location in shade or sun—competition for food, light, air—the neighbors, whether they be plant neighbors, or animal neighbors, or human neighbors—all of these, and a thousand other factors which could be mentioned, are the elements of environment—some pulling the plant one way and some another, but each with its definite, though sometimes hardly noticeable, influence on the individual plant.

And the second is heredity!

Which is the sum of all of the environments of a complex ancestry—back to the beginning.

Just as with the bear, so in plant life. In every seed that is produced there are stored away the tendencies of centuries and centuries of ancestry. The seed is but a bundle of tendencies.

When these tendencies have been nicely balanced by a long continuation of unchanging environment, the offspring is likely to resemble the parent.

But when, through a change of environment, or through crossing, that balance is disturbed, no man can predict the outcome.

So when such a seed is planted, no man can be sure whether the twentieth-century tendencies will predominate, or whether long-forgotten tendencies may suddenly spring into prominence and carry the plant back to a bygone age, in some of its characters.

"How can seeds store up the tendencies of their ancestry?" some one has asked.

"How can your mind store up the impressions which it receives?" we reply.

Hidden away in the convulsions of our own brains, needing but the right conditions to call them forth with vividness, there are hundreds of thousands, perhaps millions of impressions which have been registered there day by day.

The first childhood's scare on learning of the presence of burglars in the house may make us supersensitive to night noises in middle age.

The indelible recollection of a mother's love and tenderness may arise after forty years to

choke down some harsh word which we are about to utter.

The combined impressions of a thousand experiences with other human beings seem to blend together to help us form our judgment of a single human being with whom we are about to deal.

As the weeks have rolled into months, and as the months have melted into years, new impressions have arisen to crowd out the old; strong impressions have supplanted the weak, bigger impressions have taken the place of the lesser ones—but the old impressions are always there —always blending themselves into our judgments, our ambitions, our desires, our ideals—always ready and waiting, apparently, to single themselves out and appear before us brilliantly whenever the proper combination of conditions arises.

So, too, with the seed.

Every drought that has caused hardship to its ancestors is recorded as a tendency in that seed.

Every favoring condition which has brought a forbear to greater productiveness is there as a tendency in that seed.

Every frost, every rain, every rise of the morning sun has left its imprint in the line of ancestry

A NEW PLUM AND ITS WILD ANCESTOR

When plants grow wild there is little need for large quantities of luscious meat; but as they come under cultivation the stone grows less and the meat not only more, but better. This direct-color photograph print is of one of my largest hybrid plums and of a wild plum, such as grows in the woods near Santa Rosa; both are the actual size. The large one was raised from the seed of the small one here shown.

and helped to mold tendencies to be passed on from plant to plant.

Beneath the wooden-looking, hard-sheathed covering of the seed, there is confined a bundle of tendencies—an infinite bundle—and nothing more to give its product character.

One tendency stronger than another perhaps —a good tendency suppressing a bad tendency —or the other way, tendencies inherited from immediate parents, tendencies originating from the influences of twenty centuries or more ago—tendencies which are latent, awaiting only the right combination of conditions to bring them to life; all of the tendencies of a complex ancestry—some lulled to sleep, but none obliterated; that is a seed.

The whole life history of a plant is stored away in its seeds.

If we plant a great number of the seeds we shall be able to read more or less clearly its life history with its variations, its hardships, all of its improvements and retrogressions uncovered before us.

Who knows what little thing will change a career? Or what accident will transform an ideal? Or what triviality, out of the ordinary, will lead to the discovery of a new truth?

The potato seed ball is an insignificant-looking fruit, of no use as any ordinary practical farmer would have said.

Away back in the history of the potato, on the bleak Chilean mountainsides where it had to depend almost wholly upon its seeds instead of tubers for reproduction, every healthy potato plant bore a great number of seed balls and this is the case even at the present time in the high Andean region and down in the canyons and valleys of Chile, wild potatoes are one of the worst of weeds, though in some cases producing fairly good small potatoes.

But years of cultivation have removed from the potato the necessity of bearing seeds for the preservation of its race. The potato plant, so certain now to reproduce itself through subdivision of its tuber, so reliant on man for its propagation, has little use for the seed upon which its ancestors mostly depended for perpetuation before man relieved it of this burden.

So the average potato grower, knowing that next year's crop depends only on this year's tubers—and being more anxious, alas, to keep his crop at a fixed standard than to improve it—might see the occasional seed ball without knowing its meaning—or realizing its possibilities.

I had been raising potato seedlings for amusement at Lancaster, Mass., in 1862 and 1863, but all the potato seedlings which I had raised had so generally almost exactly resembled the parent plants that I had given up the effort to produce anything of special value from any of the common varieties.

No one, up to the present time, as far as we have learned, has ever seen a seed ball on the Early Rose potato, except myself, and for years I had a standing offer of five dollars per fruit for anyone who would furnish me another from the thousands of acres which were raised of this variety at that time.

This seed ball attracted my attention from knowing that the Early Rose did not bear seeds and it was watched patiently from the time it first formed on the vine until it was nearly ripe.

When one day I went to examine it, as I did often, it had disappeared and every effort to find it for a time failed, but at last it was discovered a short distance from the plant where perhaps a bird, a dog, or some other passing animal had brushed it from the vine.

Although I was raised on my father's two-hundred-acre farm—a large one for New England—and began my experiments there, yet my own little twenty-acre farm in an adjoining town

has, by the product of the "Burbank" potato, increased the wealth of the world very greatly, and this without the cost of a dollar except the $150 which I received for it from a well-known eastern seedsman.

In the month of May, 1872, in this little New England town, I held in my hand one seed, ten of which were not as large as an ordinary pin head. From this tiny seed the "Burbank" potato came. More than six hundred million bushels of this potato have been raised during the past forty-nine years; enough to make up a solid train of potatoes to reach 14,500 miles, or more than halfway around this planet.

The interesting fact to be noted here is that from this seed ball were produced twenty-three new potato plants.

Each of these plants yielded its own individual variations, its own interpretation of long-forgotten heredity and numerous natural crossings.

One, a beautiful, long, red potato, decayed almost as soon as dug; another was red-skinned with white eyes; another white with red eyes; two white ones and several had eyes so deep that they were unfit for use, and all varied widely.

These twenty-three variations, in fact, may have represented as many different stages in the history of the potato family; and, having no

present-day environment to hold them in balance, all were more or less unlike any potato which had ever been cultivated.

Among the number, though, was one variety better than the rest—and better than any potato which had ever been seen. This variety was named the "Burbank" by J. J. H. Gregory, a well-known seedsman of eastern Massachusetts.

With the same work—indeed with less—both the pioneer who grew potatoes for his own sustenance, and the potato specialist who produced his crop on a commercial basis, were now enabled to very considerably increase their output.

And to-day, when more pounds of potatoes are grown than of any other food crop of the world, the increase made in a single year's crop — the increase gained without any corresponding increase in capital invested or cost of production—amounts to an astounding sum in the millions.

Possibly at no other time in the history of the nation could the Burbank potato have come more opportunely.

These were the days when Chicago was a far western city, and when the great territory beyond was the home of the pioneer.

The potato is a vegetable designed peculiarly for the pioneer.

THE BURBANK POTATO

An improvement in one of the most important of crops. This variety has added many millions to the wealth of this and other countries, not only by its unusual vigor and productiveness, but by its superior quality. Millions of bushels of this variety are grown annually.

It requires no great preparation either for planting or harvesting. It grows rapidly on the rich new soil turned over by the settler; a little cultivation insures its growth; when ripened it may lie in the ground and be used as needed; when the fall frosts come it can easily be banked in a pit for winter use.

Little care; small outlay; easy preparation for food; these make the potato among the first crops to be grown when the settler locates his new home.

Trace now the influence which this one success had upon a growing nation. It was in 1872. It was a time when the line between success and failure — between starvation and comfortable plenty—was drawn so finely for the pioneer that even the slightest help was of a value out of proportion to its intrinsic worth.

A crop failure or shortage, in those reconstruction days after the war, meant a set-back that would take years to overcome, for the pioneer's only source of supply, usually, was his own crop.

Any increase, therefore, in nature's products —such as the potato—in the days of the pioneer, signified more to the world than it ever has since. The greatest value it gave—the greatest service it performed was to help the world to know the

value of improved plants which could increase the amount of crops without any added expense whatever.

Plant potato eyes, and you get potatoes like the parents—improving or retrograding a little, according to the present environment in which they grow.

But plant potato seeds, and you tap a mine of heredity, infinite in its uncertainties, but infinite too in its possibilities.

During the past twenty-five years I have produced and introduced a hundred or more new plants which give promise of being as valuable as the Burbank potato—a large portion of which have already proven so—though not yet as widely known and grown, and also have hundreds yet to introduce as priceless in value as these.

Heredity is the sum of all of the environments of an infinitely complex ancestry back to the beginning.

NO TWO LIVING THINGS EXACTLY ALIKE

Infinite Ingenuity the Cost of Variation

WHERE do the flowers get their colors? From the bees, and the butterflies, and the birds—and from us.

Let us pick up a carnation or any other common garden pink (*Dianthus*), a class of plants very commonly cultivated in greenhouses and out-of-doors.

If we were to strip off the petals soon after they have opened, and slice the base of the blossom in half, we should find ourselves looking into a tiny, long cylindrical nest of dianthus eggs—soft, white, moist, mushy eggs with only a soft, skinny covering for shells.

Carefully packed in a pulpy formation, these eggs, we should observe, are incased in a well protected nest, longer than its breadth, oval, except that its top extends upward in the form of a single tiny stalk.

Surrounding this neatly packed nest of eggs with its single upright stalk, and hugging it closely all around, we should see very slender modified leaves, half an inch or so in length, ending each in a pointed stalk as large around, perhaps, as a bristle out of a hairbrush, arranged in circular form as if shielding the egg chamber and its central stalk from harmful intruders.

At the top of the surrounding stalks we should see crosswise bundles, nicely balanced, or beautiful slaty gray pollen dust, loosely held in half-burst packages.

At their base we should find the dianthus honey factory, also the fragrance factory—a group of tiny glands which manufacture a sticky confection that covers the bottom of the flower with its sweetness and fragrance.

Shall we take one of the egglike seeds from its nest and plant it? We might as well plant a toothpick.

Shall we take a package of the pollen, and put it into the ground? We might as well sow a pinch of flour.

But let us combine a grain of that pollen with one of those eggs and ten days in the soil it will show us that we have produced a living, growing thing—a new dianthus plant, with an individuality, a personality of its own—an infant dian-

thus, which we for the first time have brought into being—a thing which had never lived before, yet which has within it all of the tendencies inherited from ages of ancestry—which wait only on environment to determine in a slight degree which shall predominate.

By the simple combination of the pollen and the egg we have produced a new individual which may, if we have the requisite knowledge in choosing the parents and will it, become the founder of a whole race of new and better carnations.

How shall we go about it to make a combination such as this between the pollen dust and the seedlike egg so snugly stowed away within its nest?

Let us examine that central stalk inside the guard of pollen-bearing stamens and few or many petals, and we shall have the answer.

As the stamens fall away we begin to see a transformation in the central stalk. Its upper end, which at first was single, now shows a tendency to divide into two or three curling tendrils—moist and sticky, covered with hundreds of little fingers to still further catch and hold the pollen.

Though we may plant pollen in the ground without result, we have but to place it on one of these stigmas as they curl from the end of

THE GERANIUM READY TO RECEIVE POLLEN

As soon as the pollen has been removed by insects from the geranium, its anthers and stamens shrink and wither away, disclosing the pistil which they have surrounded. The pistil then uncoils into five curling lobes, upon whose sticky surface the pollen from other flowers finds lodgment.

that central pistil stalk to start an immediate and rapid growth.

Once planted there, the pollen grain begins to throw out a downward root, into and through the pistil stalk—forming itself into a tube which, extending and still extending, finally taps the egg chamber and makes possible a union between the nucleus of that pollen grain and the egg below which awaits its coming.

So, to produce a new dianthus, we have but to dust the grains of pollen upon the stigma of that central pistil stalk; and when the flower has withered away, its duty done, we shall soon find within the egg chamber a package of fertile dianthus seeds ready for planting.

But there arises now a difficulty. While those little packages of pollen dust are there, the central pistil stalk inside keeps shut up tight, and it has no sticky surface on which to dust the pollen and no little fingers to catch and hold it.

And if we search for another blossom which shows an open, sticky pistil, we shall always find that the pollen packages which once surrounded it have passed away.

To make a combination between the pollen grains and the egglike seeds, therefore, we find it necessary to search first for one blossom which

is in its pollen-bearing stage, and then for another blossom which has passed this point and shows a receptive stigma—we are forced to make the combination between the two, instead of between the pollen grains and the eggs of the same blossom.

If the stigma of a blossom were at its receptive stage when the pollen packages around it were bursting open, there would probably be combined in the seeds of its egg chamber below only the characteristics of one parent plant—only the tendencies of a single line of ancestry.

But when these eggs have brought to them the pollen from another plant, there are, confined within them, the tendencies and characteristics of two complex lines of ancestry; so that the plants into which they grow will be encouraged into variation and individuality, not as a result of environment alone, but as a result of the countless tendencies inherited from two separate lines of parentage.

What a scheme for pitting the old tendencies of heredity against the new tendencies of environment—what an infinite possibility of combinations this opens up!

Truly, of a million dianthus blossoms no two *could* be exactly alike—nor any two of their millions of petals—nor any two of their millions

of stamens—nor any two of their millions of honey glands—nor any two of their thousand million pollen granules.

What we have seen in the dianthus—those egglike seeds, the sticky stigma and that microscopic pollen dust, we may see in some form or other in every flowering plant that grows.

The act that we might have performed to produce a new dianthus plant—the combination of the pollen with some of those eggs is going on about us always, everywhere—by the bees, the butterflies, the birds, the winds, and numerous other agencies acting to effect these combinations. Which is the reason for the candy factory at the bottom of every carnation's little central well. And for those brilliant petals, and that delicate fragrance and the arrangement of the stamen stalks, and the crosswise poise of their pollen-bearing anthers, and the central pistil stalk which rises upward from the egg nest and everything that is beautiful and lovely in the bloom of that dianthus—and the dianthus itself.

Here is a plant, the dianthus, so anxious to produce variations in its offspring that it has lost the power of fertilizing its own eggs and risked its whole posterity upon the cooperation of insects or other means for bringing pollen from some neighboring plant.

A POLLEN-LADEN BEE

This direct-color photograph print shows a bee, greatly enlarged, which was captured in a cactus flower. The pollen grains can be seen sticking to its hairy body, and the fact that, as it crawls into the next flower, some of this pollen will find lodgment on the sticky surface of a receptive stigma is easily realized. The bees gather pollen not only for distribution but for their own uses. The two large splotches of pollen shown beneath the second pair of legs are "pollen dough" or "bee bread" which the bees carry home for food.

It has no power of locomotion—no ability to get about from place to place in search of pollen for its eggs or of eggs in need of its pollen; nor has its neighbor, so they call in an outside messenger of reproduction—the bee.

The dianthus secretes its honey at the base of its blossom. It places movable packages of pollen dust balanced on springy stamens in such a way that, to reach the sweets, the pollen hedge must be broken through. It keeps its egg chamber closed and its pistil unreceptive while the pollen dust is there, and, as if to advertise its hidden sweets to the nectar-loving bees, it throws out shapely petals of many brilliant hues and exudes a charming fragrance.

And thus the bees, attracted from afar, crowding into the tiny wells to get their food, become besmeared with pollen dust as they enter a pollen-bearing bloom — and leave a load of pollen dust wherever they later brush some receptive stigma.

Why did the dianthus gets its color?

For the bees.

Just as the cactus covered itself with spines until it had built up an effective armor, in the same way the dianthus, by easy stages, has worked out a color scheme to attract the bees upon which it depends to effect its reproduction.

On my Sebastopol farm there was once growing an arum (*A. dracunculus*) whose color and scent reveal a somewhat different history.

Unlike most flowers which advertise themselves by a pleasing fragrance to attract bees, birds, and butterflies, this plant produces a scent to attract carrion flies.

Some flies feed on carrion. The nectar of the clover is not to their liking and the brilliant colors of our garden flowers fail to attract them. Our refuse is their food, and they are guided to it by colors and scents which are highly offensive to us.

So this arum, or carrion lily, as it has been named—stranded at some time in its history, perhaps, in some place where flies were its only available messengers of reproduction, or blooming at a period when other means were not within its reach—has bedecked its spathe with a brownish-purple color, resembling the color and texture of a piece of liver or an overripe beefsteak.

Just as the dianthus supplements its advertisement in color with an advertisement in fragrance, so the carrion lily has developed an individual odor appeal, decidedly like that of meat of uncertain age and quality.

So obnoxious and so penetrating is the odor of this flower that each year it has been found necessary to cut off and destroy the blooms as soon as they appear.

And so truly has it achieved its ideal that even the buzzards, carrion birds that they are, attracted by its color, its texture, and its smell, have descended in ever-narrowing circles only to fly away in disgust when they found they had been lured by a flower.

Where the dianthus finds it satisfactory merely to block the entrance to its honey store with an array of pollen bundles which must be pushed aside by the entering insect, the carrion lily makes doubly sure of pollination by means of a still more ingenious device.

The fly, attracted by the color of the spathe and guided by the hidden odor at the base of the flower, lights on the sturdy spadix and uses it as a ladder for descent. The opening around the spadix is just large enough to afford a comfortable passageway; but once within the well, the spathe closes in and snugly hugs the spadix, so that the fly, buzzing about in the chamber below, becomes thoroughly covered with the pollen dust.

This done, the flower slowly unfolds and permits the pollen-laden insect to escape.

Many other flowers show equal or greater ingenuity.

In some varieties of the sage, the pollen-bearing stamens actually descend and quickly rub the yellow dust on either side of the insect, after which they fall back into their former position above the nectar cells.

The orchids, almost without exception, show a most marvelous ingenuity.

Some of the species bear their pollen in small bundles, the base of each bundle being a sticky disk. The structural arrangement of the flower is such that the insect cannot secure its nectar without carrying away at least one of the bundles. A pollen bundle glues itself to the head of the insect and curves upward like a horn.

As soon as the insect has withdrawn from the flower, this pollen horn bends downward in front of the insect, so that when the next flower is entered the dust can hardly fail to reach a receptive portion of the stigma.

In these orchids there are but single receptive stigmas and the pollen bundles are separate and single also, but in another orchid which has two receptive stigmas, the pollen bundles are in doublets, held together with a strap.

Thus the insect visiting this second orchid carries away two pollen bundles on its forehead,

each so nicely placed that their dust will reach both sticky stigmas of the next flower entered and could not pollinate the stigma of the first mentioned orchids.

Orchid pollen is quite often carried by small birds as well as very large insects and the contrivances which the orchids have invented to prevent pollinization from other species of orchids are marvelous almost beyond comprehension.

Similarly, the pollen of the milkweed is stored in two little bags, connected by a strap. When the bee visits the flower its feet become entangled in this strap and when it leaves it carries both bags with it.

And so, throughout the whole range of plant life, each fresh investigation would show a new display of ingenuity—infinite ingenuity directed toward the single end of combining the tendencies of two lines of heredity—so that the offspring may be different from and better equipped than the parents for adapting themselves to new conditions of environment.

We may observe a number of species of flowers which bloom at night only; flowers which, as if having tried to perfect a lure for the insects of the day, and having failed, have reversed the order of things and send forth blossoms of

ARUM DRACUNCULUS — A FLY-LOVING FLOWER

The carrion lily pictured here advertises to the flies to act as its messengers of pollination. The spathe frequently grows to fifteen inches in length, and as can be seen, though rich and almost attractive in appearance, is of the same color as a piece of decaying liver. The smell emitted from this flower is offensive in the extreme—all for an advertisement for flies, which surround the plants in great numbers when in bloom.

white or yellow — luminous colors always — to attract the moths that fly after the sun goes down.

As far as I have observed, no flower which blooms exclusively at night has any other color except yellow or white.

We should find many interesting half hours of wonder contemplating such flowers as the honeysuckle, the nasturtium, the aquilegias, some clovers, and many of the lilies—which have taken special precaution to place their nectar in long, hornlike tubes, out of the reach of most insects, so that only the birds or insects with an unusually long proboscis may become their messengers of reproduction.

We should see the pathos of those flowers which advertise for insects that rarely come. The barberry, for example, which can be pollinated only during the bright hours of a cloudless day, and during a time so short that there is little chance of pollen being brought by insects from other blossoms. Each barberry blossom, ready for the insect if it should come, but as if expecting disappointment, makes sure of self-perpetuation, if not of self-improvement, by jabbing its pollen-laden anthers on its own stigma with a motion as positive and as accurate as the jump of a cat.

Or the fennel flower (*Nigella*) of France, in which the several pistils bend over and take pollen from the stamens around them and straighten up again.

Or the flowers of the nettle (*Urtica*) in which the stamens increase their height with a sudden springlike action, showering the pollen up over the receptive stigma.

We should observe that wheat and most of the similar other grains, as though discouraged by centuries of collective cultivation, or failure to secure individual selection, had settled down to the steady task of reproducing their kind almost exactly alike, depending on similar individual environment for slight individuality, and insuring reproduction for self-pollination, with rare exceptions.

We should see plants in all stages of their attempts to keep their kind fully adapted to their new and constantly changing environments; we should see a range of ingenuity so great that no man, no matter how many of his days have been devoted to the study of plants and their ways, can ever become weary of its wonders.

"I bought some extremely expensive seed corn several years back," complained a Santa Rosa farmer. "But, just as I expected, it ran down. The first year's corn was fine, and so was the

second; but now it has gone clear back to ordinary corn. This plant improvement does not pay."

Do you know how corn reproduces itself?

Do you realize that if you plant good corn on one side of the fence and inferior corn on the other, the corn cannot see the fence?

Would you expect that a cross between a race horse and some family dobbin would produce a line of racers?

Separate your good corn from your poor, and keep it by itself, and you will find that it does not "run out," but even gradually, by careful selection, improves each season.

Every farmer knows that corn must be planted in large quantities close together—that a single kernel of corn, planted in one corner of a lot, apart from other growing corn, would be nonproductive.

Yet how many of those who depend upon corn for their living fully realize the reason for this?

The dianthus, with its nectar, its fragrance, its color, and its structural arrangement, has built up a partnership with the bee to perform its pollination; while corn, with no advertisement, no honey, no brilliant reds, no fragrance, has developed an equally effective plan of

making the breezes act as its messenger of reproduction.

Here is a plant, tall and supple, that responds with graceful movements to the wind. At its top it holds a bunch of pollen-laden tassels—swaying tassels which, with each backward and forward movement, discharge their tiny pollen grains in clouds, which slowly settle toward the ground.

Below, on the stalk of the plant, are the ears of corn, containing row after row of egg kernels, needing but combination with pollen grains from above to become, each, a seed capable of starting another corn plant on its life.

Just as the eggs of the dianthus were housed in a protective covering, so the corn eggs are sheathed within protective husks. And just as a tiny stalk protruded from the egg chamber of the dianthus, so does the long silk which protrudes from the end of the husk serve the same purpose for the corn seed.

Remove the husks from an ear of corn, and it will be seen that each strand of the protruding silk goes back to one individual kernel on the ear. That, between the rows of kernels, like electric wires in a conduit, each strand of the common bundle of silk protruding leads back to its separate starting point.

To combine the characters of two parent corn plants, all that is necessary is to dust the pollen from the tassel of one on the silken ducts of the ear of another.

And the breezes, as they swish a waving field of corn gracefully to and fro—as they play through a forest of pines, or as they ripple the grasses of our lawns—are performing their function in the scheme of reproduction as effectively as the bee does when it goes from dianthus to dianthus in search of sweets.

Consider the simple salt-water cell, as seen reproducing itself under the microscope merely by splitting in two; and those two each becoming two, and so on, endlessly.

Observe that, with only a single line of parentage from which to draw tendencies, the individuals to be found in this, the lowest form of life we know, are molded wholly by the variation in its temperature, or those other limited changes within a short-lived environment.

And then consider the dianthus, the arum and the orchid—with a thousand added complications in their lives brought about by a single dominant purpose—a thousand self-imposed difficulties and obstacles which would be needless except for that guiding desire to give the offspring a better chance than the parent had!

What a price to pay for variation! What ingenuity and effort each new combination of heredities has cost! How many must have been the plants which advertised for insects that did not come! How many, finding themselves in an unequal struggle, have perished in the attempt!

Truly, if the cost of things may be taken as a measure of their value, how much must this dearly bought variation be worth in the Scheme of Things!

The struggle of a plant to secure adaptability for its offspring does not end with the seed—it only begins there.

In the tropics, a common tree near the seashore is the coconut palm. The coconuts which we find in our market are but the inside portion of the nuts as they grew on these trees.

When they were gathered there was a fibrous substance surrounding the shell an inch or two in thickness—this woody fiber is often removed by the shippers to cut down the cost of freight and cartage. Around this excelsiorlike covering, as the nut grew on the tree, there was a skin-tight, waterproof cover, with a smooth shiny surface.

At one end of the nut are three well-defined eyes—very thin places in the shell.

Since these coconut palms grow, usually, along the water's edge, the nuts sometimes fall into a brook, a river, or the ocean and float away.

Once detached from the tree and started on such a journey, the eyes disclose their purpose. One of them throws out a system of roots, not on the inside of the hard shell, but growing at first within the woody fiber between the shell and the outside covering.

These nuts may float in the water, even salt water, for thousands of miles, while strong, vigorous roots are forming on the inside of the covering among the excelsiorlike packing.

Once landed, after weeks, perhaps, of travel, the roots cast anchor by forcing themselves out into the moist soil at the water's edge. Two or three sturdy leaves soon appear, and so the new plant is established in its new home.

The hard shell surrounding the stored-up milk in the coconut is there obviously as a protection from the monkeys and other animals; to prevent extermination through their liking for the milk and the meat.

And that excelsior packing, and waterproof housing, are not these very plainly the palm's attempt to provide for its baby tree in its new environment?

THE COCONUT'S THREE EYES

The coconut, as everyone knows, has a very hard shell, this protection covering the whole nut except at one end where there are three unprotected "eyes." From one of these, when the nut sprouts to make a new plant, a strong root emerges, and a mass of roots is soon produced within the excelsiorlike covering, but inside the waterproof cover of the nut, which, for the purpose of illustration, has been removed. When the nut finds the proper environment, the roots burst forth and grow rapidly. A tall stalk soon appears, which finally becomes the trunk of the new palm.

We do not have to go to the tropics for evidences like these.

There is probably no more familiar weed in our vacant lots than the common dandelion (*Taraxacum*).

Who can forget its feathery seed ball waiting when ripe for the first youngster, or the first draft of air to blow it away on its long sail through the air as it distributes its seeds—some on stones, perhaps, and some on plowed ground, or in our lawns where it becomes a pest — such a multitude of seeds that, though many be lost, some will find themselves throwing roots into new soil — starting life in a new environment.

Or we might learn a lesson from one of the wild chicories (*Cichorium*) which provides some of its seeds with wings to fly, while others it leaves wingless. Those seeds without wings fall at the feet of the parent plant as if to keep green the old family home; while those with wings fly away to start new families, under new conditions, where patent traits and tendencies—latent elements of weakness or strength—may cooperate to produce a chicory better adapted to its new environment.

Or from that joy of childhood, the squirting cucumber (*Ecballium*) which, when ripe, fires its

THE DEVIL'S-CLAW—I

As it grows in the tropics, or in our gardens, the seed pod of the devil's-claw, or martynia, shown here, resembles a gourd in color and in texture of its covering. The succeeding prints show how it transforms itself to bite and hold on to passing animals with a bulldog grip. The young fruits are sometimes used for pickling.

seeds with such force that they are sometimes carried a distance of twelve to fifteen feet.

Or even the sweet peas, or our garden pea, which when their pods have dried, have the ability to throw the seeds some distance from the parent plant.

In Mexico there is the familiar bronco or jumping bean, belonging to the spurge family, which calls in an insect to aid in the distribution of its seeds.

While these beans are still green, they are visited by a moth which lays her eggs in them. As they ripen, the grub hatches out and lives upon a part of the food stored within.

As if in partnership with the moth, the jumping bean tree has provided food for her offspring, so that the larva has plenty to eat without injuring the seed within the bean.

And the grub, as it hollows out the bean and jumps about within it, causes it to turn and roll—rolls it into a new environment—repays its family debt to the tree which gave it food.

The devil's-claw (*Martynia*) has developed a curious power to bite and cling with bulldoglike grip, in its scheme of providing new environments for its young.

This spreading tropical plant requires considerable room to perfect its growth, growing low

THE DEVIL'S-CLAW—II

Martynia seed pod in the act of shedding its outside covering, leaving the sharp claws ready for business.

on the ground among other vegetation where the distribution of seed becomes a problem, grows a seed pod of seven inches or more in length.

Its seed pod, while maturing, is incased in a pulpy covering with a thick green skin, and its bulb and hook suggest some kind of gourd.

When the seeds within are mature, the outside covering splits and peels away, disclosing a seed nest which is armored with spines as thickly as a prickly pear. That which, during its early stages, formed the hook, now spreads into two branches with pointed ends as sharp as needles.

Between these four-inch hooks, where they join the spiny bulb behind them, there appears a hole from which the seeds, if loosened from their former pulpy support, may, by pounding and thumping, find their way one by one out into the world.

As the seed pod lies on the ground, its sharp hooks coiled in exactly the right position, it awaits a passing animal. This spring trap may remain set for many months, but once an animal, large or small, steps between those fishhook points, their mission is with great certainty accomplished. The first slight kick or struggle to get away, imbeds them more deeply, and at each succeeding struggle the hooks bite in, and in, until finally the animal starts to kick and run.

THE DEVIL'S-CLAW—III

Having completely shed its gourd-like covering, and with its jaws set for a passing animal, it will be seen that the pod itself is covered with prickly spines. When the fishhook points of the prongs bite into the leg of an animal, the whole contrivance becomes balanced from these points, and at each jolt and jounce the heavier body of the pod pounds down upon the leg, its spines causing great pain. There is a small opening between the two prongs at the upper end of the pod itself from which the seeds come out, one at a time, at every bounce. When these are scattered over a mile or two of new environment, the pod has performed its appointed mission.

Swinging to a leg or tail, suspended by the two sharp points of its prongs, the spiny housing of the seed pod now comes into play. At each bound or jump, the pod flops up and down and its prickly points, adding to the pain of the ever-pinching hooks, are sure to keep the animal in motion. As the frightened beast makes haste to get away from an enemy which it cannot see, the seeds within the pod are shaken one by one through the narrow opening, falling on the ground.

The sailor is awed by the mountains, and the mountaineer is awed by the sea.

And we, too, are more apt to wonder at the jumping beans of Mexico and at the devil's-claw of the tropics than at the cherry tree in our own back yard — which outdoes both of these by forming a double partnership.

Just as the dianthus bids for the bees, so the cherry blossom, with its delicate pink and its offering of fragrance and honey, advertises for butterflies and bees to bring the pollen from some neighboring tree.

And this partnership concluded, the accounts balanced, and the books closed, it then seeks new partners in the birds.

That delicious meat around the seed, that shiny skin of red, and that odor of the cherry as it

ripens—these are a part of the advertisement to the birds or animals—a lure to get them to eat the fruit and carry the seed as far away as they may to another—a new—environment.

Shall we wonder at the jumping bean and the devil's-claw when our own cherry tree is getting the bees to give its offspring new heredities and the birds to surround these heredities with new environments in which to grow?

Wherever we look we see a new display of ingenuity—all for the sake of variation—variation which may mean retrogression as well as advancement—but such infinite variation that, surely, there can be found one out of a thousand, or one out of ten thousand, or one out of a million better adapted than those that went before.

Every flower that delights our eye, and every fruit which pleases our palate, and every plant which yields us a useful substance, is as delightful as it is, or as pleasing or as useful as it is, simply because of the improvement which has been made possible through variation.

No two living things are exactly alike.

THE RIVALRY OF PLANTS TO PLEASE US

On the Forward March of Adaptation

"WE cut our alfalfa four or five times each season," says some one, "why doesn't it grow spines to protect itself? We destroy our lettuce before it goes to seed; why doesn't it develop a protective bitterness like the sagebrush?

"We rob our apple trees of all their fruit the moment they are ripe; why do they not become poisonous like the desert euphorbias?"

As we have taken the cactus as an example, let us go back to it and read the answer.

Grim and threatening though the cactus seems, it is not without its softer side; in the springtime its blossoms, a multitude of them, push their way through the spiny armor—and rival the rose in beauty of form and color, even competing with the orchid in the delicacy of their hues.

No favorite garden flower can outdo this ungainly monster of the desert, when in bloom, in the seductiveness of its advertisements put forth to attract insects.

When summer comes, and the insects have paid, by the services rendered, for the honey taken, the nest of fertile eggs beneath each cactus blossom begins to grow into a more or less luscious fruit.

In this cactus fruit there is a sweetness which makes the fruit as tempting as that of the strawberry, raspberry, banana, or orange. Its outer covering, in some of the improved varieties, is as beautiful and varied as that of the apple or the peach.

Thus, in the springtime, the cactus, like the cherry, advertises to the friendly insects to bring its offspring new heredities, and in the fall it advertises to the friendly birds to carry off its seed and plant it where its young may have the advantages of new environment.

In its brilliant flowers and tempting fruit we read its receptiveness to the friendship of the birds and bees.

Those spines and flowers and fruits tell us that, while its ancestors were fighting a common foe, they still found time to build up lasting partnerships.

And so, with every plant that grows, we shall see these same tendencies—instincts shall we call them?—to ward off the enemy and make use of the friend.

So long as plants grow wild, the frosts, the winds, the hailstorms, the droughts, and the animals are principal among the enemies with which they have to reckon.

So long as they grow in the woods, or on the mountains, or in the deserts, the bees and the birds and the butterflies — the warmth of the sun and moisture and fertility of the soil —these are among the friendly factors in their lives.

But when we take plants under cultivation, we upset their whole environment.

We build fences around our blackberries so that they need no thorns. We save the seeds of our radishes, and the bulbs of our lilies, and through human organization distribute them and plant them wherever they will grow. We cut grafts from our apple trees and ship them from county to county, and State to State, and nation to nation, and zone to zone. We select, and improve, and plow, and harrow the ground for our plants; we water them when they are dry; we surround them with shade trees if they need shade, we cut down the shade trees if they prefer

the sun; we plant their baby seedlings under glass, and give them every favoring condition in which to mature; we remove what for ages have been the chief problems of their lives—we take over their two prime burdens, the burdens of self-defense and reproduction.

The frosts, and the winds, and the hailstorms, and the droughts, and the animals are no longer the chief enemies of plants; for man, when he comes into their environment, is more dreadful than all of these combined—if he chooses to destroy.

And the bees and the birds and the butterflies, and the warmth of the sun, and the moisture in the soil, fade into insignificance as friendly influences when compared with that of man—if it pleases him to be a friend.

So the cherry tree and dianthus still advertise to the bees and birds, as of old.

But their main advertisement, now, is an advertisement to us; their strongest effort, now that we have become predominant in their lives, is to lure with their blossoms and their fruit—to enchant us with their odors, and colors, and lusciousness, as they formerly enchanted only the bees—to win and hold our appreciation and affection, and merit our kindly attention and care.

Our alfalfa, lettuce, and apples, like our horses, our cows, our dogs, have found in man a friend stronger than the strongest of their enemies.

So their welfare now is measured by the usefulness of service they can render in repayment for man's care.

There is a common snowball in my yard which advertises alone to me.

In the woods around there are other snowballs of the same family—wild snowballs—into whose life history man, as a part of environment, has never come, except perhaps to destroy.

The wild snowball, with only a fringe of blossoms, and a mass of egg nests and pollen inside the fringe, is still advertising to the bee.

But the snowball in my yard has responded to my care and the care of those who went before me, till its stamens and pistils, as if seeing their needlessness, have turned to petals—till its eggs have grown sterile, even should an insect come.

And so, with every snowball which is grown for the beauty of its flowers—cultivation has relieved it of the need for reproduction, and what once was but a fringe of flowers has been transformed into a solid mass of blossoms.

Just as a mother cat can make a dumb appeal for the protection or the sustenance of her

THE SNOWBALL — CULTIVATED AND WILD

The upper cluster of flowers is the one which is grown for its ball of white flowers. The snowball flowers below are wild, such as grow in the woods. The wild snowball, it will be seen, uses the flowers to attract messengers of pollination to the reproductive mechanism which the outside flowers encircle. The upper snowball, however, has lost its power of reproduction by seed, and advertises to us, instead, to perpetuate its race.

kittens, an appeal no human being can misunderstand, just as strongly and just as clearly do the snowballs, by the beauty and helplessness of their self-sterilized flowers, appeal to us to see to their protection and effect the perpetuation of their kind.

Many violets, as they grow wild in the woods, bear two kinds of blossoms.

One is the flower, rich in color and often in fragrance, which is borne at the top of the plant.

The other, an egg nest without petals, odor, or beauty, or other advertisement—which is borne near the base of the plant.

The flower at the top, like the flower of a geranium, advertises to the insects to bring pollen from other plants.

The flowerless egg nest below needs no insect to bring it pollen—it pollinates itself and produces fertile eggs with only a single strain of heredity; this through necessity and not to the best interest of the heredity of the plant, though these are fertile seeds.

Some of these violets with upper and lower blossoms, particularly those which grow in the shade, never open their upper flowers—as if knowing that the friendly insects so prefer the sun that no attempt at advertisement could lure

them to the shade. These violets reproduce themselves wholly by the self-fertilization which goes on within the colorless flower below.

And there are violets of the same kind, blooming in the sunlight, which open their upper flowers so that, if visited by insects, the seed within matures; but, as if in doubt of the effectiveness of their advertisement, the lower blossoms continue to produce their inbred seed.

And there are still other violets which, as if assured of the friendship of the insects, have ceased to make the colorless blossoms below, and produce their entire output of seed at the base of the brilliant upper flower.

Here, in these three kinds of violets, is written the story of a plant's struggle with wild environment in which man has not yet become a factor; the story of an unequal struggle in which the stages of failure, partial victory, and complete triumph are clearly laid before us.

Into the life of the violet, some few hundred years ago, there came a new element of environment—man.

A single violet plant which was taken from its catch-as-catch-can existence, let us say, found itself in fine-combed soil in a shady place in some one's dooryard.

If it rained too much, drainage took up the excess. When the rains did not come, the soil was sprinkled.

Under cultivation and kindly care the discouragements of its life grew less and less, and the encouragements to thrive grew more and more.

Soon this violet, as if assured of reproduction, abandoned the blossoms at its base, and threw its energies into making bigger and brighter and more beautiful blossoms at its top. Where it had half-heartedly advertised to the bees of old, it now concentrated its efforts to win the approval of the new-found friend whose dooryard brought it opportunity.

And this is the life story of the violet which we now call the pansy.

On the one hand, in the woods, we see its wild kinfolk still struggling against unequal odds; on the other we see its own large, beautiful pansy petals, and the increased brilliancy of its hues; each a response to environment.

Truly, in the pretty face of the pansy we may read the vivid story of man's importance as a friendly element in the lives of plants.

Where do the flowers get their colors?

From the bees, the birds, *and from us.*

On the experiment farm at Sebastopol there grow two ordinary-looking pear trees which amplify the thought.

One of these trees produces abundantly aromatic, luscious, easily digested pears—a delight to the eye and to the palate.

The other produces hard but juicy pears which never become mellow and uncooked are as indigestible as the quince before I commenced its improvement.

Looking at these trees side by side, it would be difficult for the common observer to realize that their fruit could be so different. In their fruit alone do they differ.

Since these two pear trees illustrate an important point, let us begin at the beginning:

It was in Eurasia, some two thousand years ago, that man first perhaps realized that the pear fruit was good to eat.

Coming to us, then, out of the obscurity, the pear, during these twenty centuries, has spread to the east and to the west, until it has completely encircled the globe—a slow process, but one which takes place in every desirable fruit which is discovered or produced.

As Europe became more and more settled, the pear kept pace with the invaders. It followed them to the British Isles, it followed them across

the Atlantic to America. It followed them westward across this continent as the pioneers pushed their way to the Pacific.

In the same way it worked its eastward journey through Siberia, and China, and Japan—more slowly, perhaps, than under the influence of European and American hurry and enterprise, but just as constantly, and just as surely—till now, in friendly climates, it is a world-wide fruit.

Both of the pear trees described here, as in fact all of the pear trees which we know to-day, seem to have come from those common parents in eastern Europe or western Asia.

The one which bears the luscious fruit is the Bartlett pear—an excellent though common variety in the United States.

The other, with its bitter, indigestible fruit, is one which was imported from China.

The lesson which these two pear trees teach is that fruits, like flowers in their rivalry to please us, adapt themselves to the tastes, desires, and ideals of the human neighbors among whom they grow.

Here, in America, we like fruits that are soft, large, sweet, luscious, juicy, aromatic, easy to digest when eaten raw. Our pears grow that way.

In Japan and China they like fruits which are hard but juicy, suitable for pickling, preserving or cooking. The Chinese and Japanese pear trees bear that kind of fruit.

Neither the Oriental pear, nor our American type is like the original wild parent which was first discovered in Eurasia.

Each has changed—one toward one set of ideals—and the other toward another set.

If we could lay bare before us the whole history of the pear tree—if we could picture in our minds its stages of progress beginning back in the old times, say, when instead of a fruit it bore only a seed pod like the wild rose—we should see a record of endless change, constant adaptation.

We should see that soil, moisture, sunshine, and air, throughout the ages, with the aid of fruit-loving animals and man, have all played their parts in gradually transforming the pear tree into its present state.

We should see that other plants, crowding it for room or sapping the moisture from around it or adding fertility to the soil by their decaying leaves, have done their share in hastening its improvement.

We should see that the bees and butterflies and birds with their help, and the caterpillars,

locusts, and deer in their apparent destructiveness, have all served to aid the onward march.

We should see all the while a steady change for the better—sturdier pear trees, brighter blossoms, more seed, better fruit.

We should see that, with the aid of the elements, the pear tree adapted itself to exist, hardened itself to withstand many soils and many weathers.

We should see that, with the unintended aid of its plant and animal enemies, it gained strength through overcoming them.

We should see that, through the bees, it was helped into variation by combining heredities; and by the birds and animals it was helped into still further variation by wider distribution of its seeds.

Then, overshadowing all of these influences there came into its life new influences of man—man savage and civilized, Oriental and Occidental—man with a liking for pears.

In Europe and here in America, we who have grown pears have cultivated the trees which bore the largest, tenderest and most delicious pears—because those were the ones we liked best.

When we have bought pear trees to plant in our orchards and gardens, we have chosen those which would give us the kind of fruit we prefer.

The pear trees which have pleased us have received our care and cultivation—and we have multiplied them. The pear trees which have failed to produce fruit up to our ideals we have neglected and allowed to die—so that they have practically disappeared from our orchards.

The Orientals, their tastes running in opposite directions from ours, have ignored pear trees which bore the kind of fruit we prefer, and have selected, and saved, and fostered, and propagated those which gave them the hard cooking and pickling fruit of their ideals.

And so the struggle for adaptation set in motion by the soil, the warmth, cold, moisture, and the winds, was supplemented by the bees, and then by the birds and other animals, until now we can read in the result our own influence and that of the Orientals.

There are differences between our dress and the dress of the Orientals; between our religions and the religions of the Orientals; between our ambitions and the Oriental ambitions; between our architecture and the architecture of the Orient—all reflecting the national or racial differences between the ideals of the two peoples.

And just as surely as the ideals of a people influence the architecture and the literature with

which they surround themselves, just as surely as they change ambitions, mold religions and adapt clothing to their conditions; just so surely do they influence and change the characteristics of the plants in whose environment they live.

When I say that man is the most important element in the environment of plants, I do not mean those few men who devoted their lives to the improvement of plants. I do not mean the botanist, the horticulturist, the florist, the seedsman, the nurseryman, the agricultural experimentalist. I mean man in the mass—man busy with his dry goods store, or his steel company, occupied with his law, or his medicine, weary from his daily blacksmithing, or his carpentering. I mean just man, the neighbor of plants, whether he be their friend or their enemy—whoever he may be.

It was the Indian who gave us, here in America, the most important crop we have.

It was the primitive races in America who adopted one of the wild grasses and finally produced our maize; which, however, when America was discovered, was primitive in comparison to the wonderful varieties which have since been developed.

Or, to turn about, it was the desire of the Indian for a food plant like this that led the

SOME FORMS OF CORN

In the direct-color photograph print shown here the central ear is one form of the "pod" corn, in which each kernel is incased in a separate sheath. The ear at the left is another form of teosinte with larger kernels than those in the preceding print; from this latter the process by which the kernels crowded each other until the cob increased in size may be readily imagined. The ear shown at the right is an improved popping corn.

Euchlæna, or teosinte, by gradual adaptation, to produce Indian corn or maize.

On one of my experiment farms there grows, to-day, this same *Euchlæna* which the Indians found.

It bears tiny ears with two steel-armored rows of barleylike kernels on a central rachis not as large or as strong as the central stalk of a head of wheat.

And when the prehistoric and more modern races came into its environment it responded to their influence as the pansy responded to care and cultivation in its new man-protected home.

Where teosinte had formerly relied upon its own resources to find a suitable soil for its seed, it found in the Indian a friend who crudely but effectively scratched the soil and doubled the chance for its baby plants to grow.

Where it had been choked by plant enemies, and starved for air and sunlight by weeds, it found in the Indian a friend who cut down and kept at bay its competitors.

Where it had been often destroyed by the animals before its maturity, it found the selfish protection of the ancient races as grateful as though it had been inspired by altruism.

Planted in patches instead of straggling here and there as best it could before, this sturdy grass

found its reproduction problem made easier through the multitude of pollen grains now floating through the air.

And so, by slow degrees, it responded to its new environment by bearing more and larger seeds.

As the seed kernels increased in numbers and in size, the supporting coblet which bore them grew in sturdiness and length.

From two, the rows of kernels increased to four, six, eight, twelve, and now, in some varieties, to forty or more.

Here again the selfish motives of the primitive races served to help the plant in its adaptation as naturally the largest and best developed ears would be saved by some one.

So, under cultivation, the wild grass through adaptation was transformed into Indian corn.

There were two wealthy men in England who took up the daffodil and narcissus, growing endless quantities of seedlings for amusement.

Both of these men, so it happened, were bankers. One was a rather large, coarse, strong, dominating type of man—not a repulsive man by any means, but lacking a little in refinement and the more delicate sensibilities.

The other banker was a highly sensitive, nervous, shrinking man with a great eye for detail,

a true appreciation of values, a man who looked beneath the surface of things and saw beauty in hidden truths, a man who thought much and said little.

These men were rivals in their daffodil and narcissus-growing pastime, and each of them succeeded in producing some wonderful variations and adaptations in their plants.

When these bankers died, their daffodil and narcissus bulbs were offered for sale and fell into the hands of a friend of mine, Peter Barr, a great bulb expert of England.

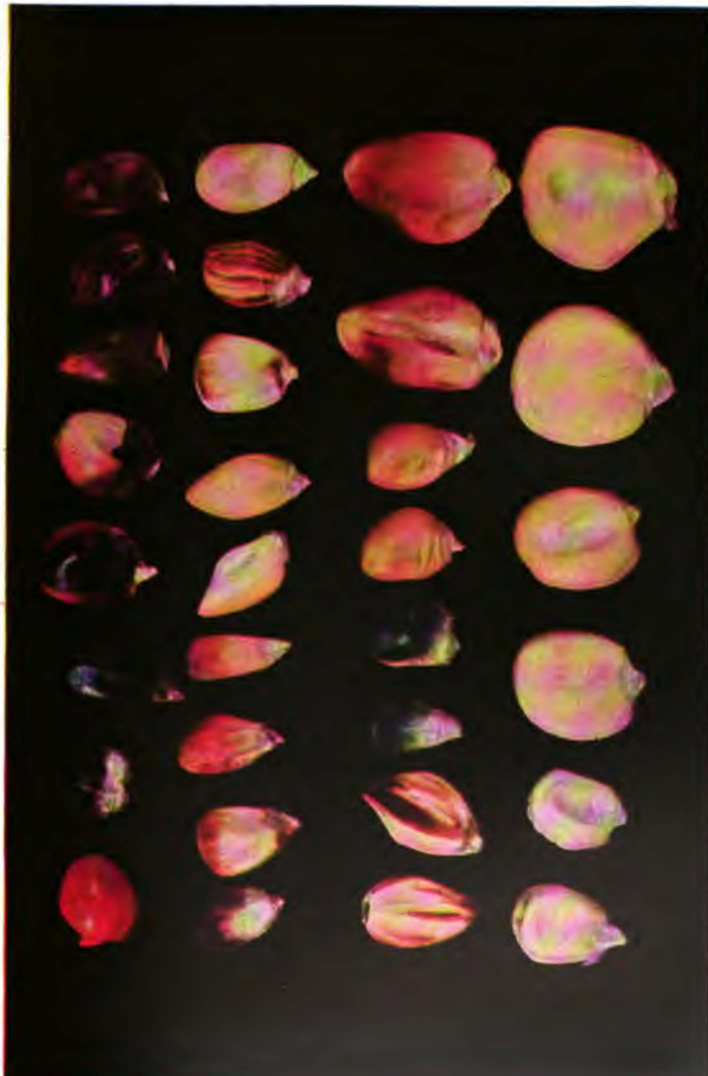
Peter Barr told me that though the bulbs bought from those two estates were mixed and planted indiscriminately on his proving grounds, he could go through a field of those daffodils and narcissus and, simply by the blossoms, tell which had come from one estate and which from the other.

The flowers that came from the bulbs that represented the work of the first mentioned banker were large, strong, coarse, brightly colored flowers—with a beauty that called to the passer-by as loud as if with words, and a self-reliant attitude as if bespeaking an ample ability to take care of themselves.

And the flowers which came from the bulbs produced by the second mentioned grower were

VARIATION IN CORN SEED

Material has been found for most of the corn experiments in variations as to one quality or another that appear among plants of the same species. It may or may not be necessary to accentuate variation by hybridizing experiments. The range of variation that may be shown in the seed of a single species is illustrated in this lot of kernels of corn, which show surprising diversity in shape, size, and color. Numberless new varieties could be developed through selective breeding from such a lot of seed as this, not only as to form, size, and color, but in productiveness, quality, and every other desirable character.



charmingly delicate—unobtrusively artistic—not loud in color, but gently alluring.

It costs money to ship oranges, so the more the meat and the less the rind, the less we waste in transportation charges.

A comparison of the wild orange with the cultivated fruit of our orange groves shows how this fruit has adapted itself to our ideas of economy.

Lettuce in the head makes a more appetizing salad than lettuce in large, sprawling leaves.

A comparison between wild lettuce and the head lettuce on our green grocer's stand shows plant adaptation in a most wonderful way to our tastes.

And so with celery, and artichokes—and every plant that is grown for the market—wild, its adaptations are toward meeting wild environments; cultivated, its adaptations are selected toward fitting itself into our routine of life.

We have seen the price which variation costs; now we begin to see the value of it. Among those violets, environment—the environment of the present combining with heredity which is the recorded environment of all the past—contrived to see that there were no duplicates; that each violet, a little different from its mate, might, through its difference, be suited to a separate

purpose, or fitted to carry a separate burden, or designed to fill a separate want.

If the violets had been as like as pins, they would have stayed as like as pins when planted in that friendly dooryard.

But because each had within it the power of transmitting variation, the power of responding, ever so little, to the trend of its surroundings, one violet became a pansy.

Among our human acquaintances we know those who are sturdy, and those who are weak; those who have well-developed minds at the expense of their muscles, and those who have well-developed muscles at the expense of their minds, and those with a more evenly balanced development; we know some who are tall and some who are short; some with brown eyes and some with blue; some who lean toward commerce, and some who lean toward art; and on and on, throughout an infinite number of variations, an infinite combination of these variations, each variation representing the result of present environment reacting upon all the environments of the ages, stored away.

As a people, we traveled by stage till the railroad came; and then in a single generation, because of the variation and the adaptability among us, we found surveyors to push their

transits over the hills, and valleys, and streams; we found woodchoppers to make ties, we found steel makers who for the first time in their lives fashioned a rail, we found engineers, and firemen, and switchmen and superintendents, and railroad presidents, each to play his part in fulfilling the great common desire for transportation, each able to adapt himself to new duties—and all because of this acquired variation that is within us.

As a people, we submitted to a ruler across the seas till among our variant individuals there arose some who, different from the rest, adapted themselves to the formulation of a declaration of independence, the framing of a code of principles, the organization of a successful revolution.

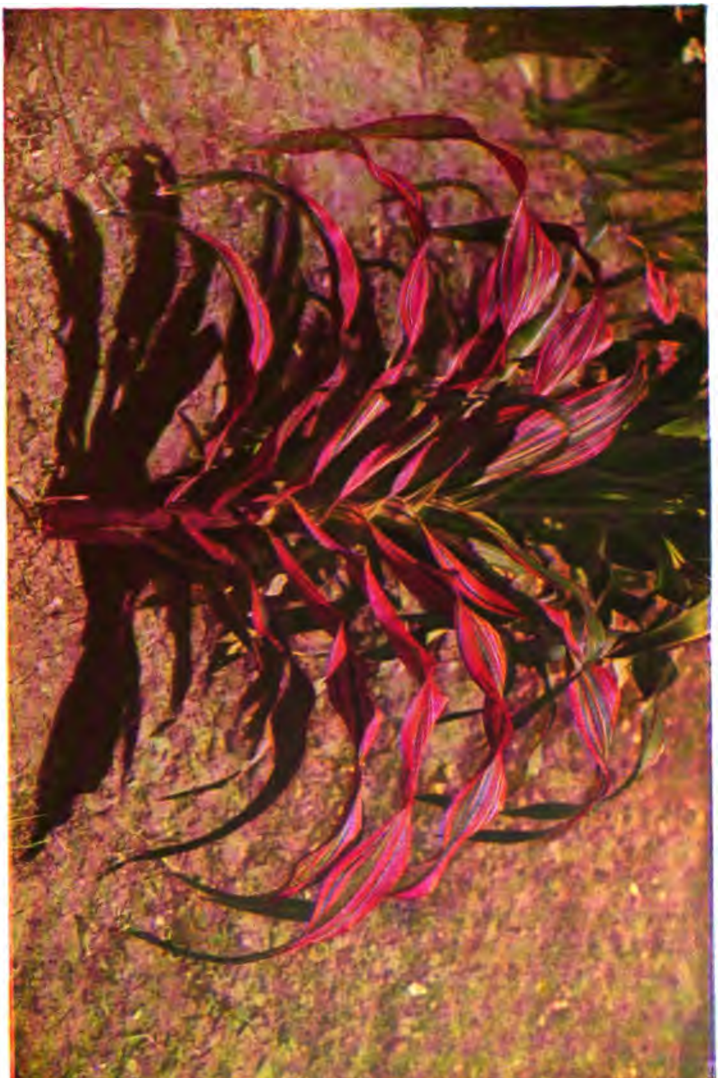
As a people, threatened with the constant peril of cures which were worse than their diseases, there appeared out of the variable mass one who gave us antiseptic surgery.

Where are those who, a century ago, said that railroads could never be? Where are the Tories of revolutionary times? And where are those barbers of ancient days with their cupping glasses and their lancets and their leeches?

Ah, where are the pear trees of Eurasia that failed to fit into the scheme of adaptation—where

RAINBOW CORN

In previous chapters of this volume there have been shown several direct-color photograph prints bearing on the evolution of corn. The plant shown here is still another variation, grown only for ornamental purposes, which has been brought about. As can be seen from the print, the leaves take on the brilliant colors of the spectrum—bright reds, yellows, and purples intermingling with the green. For decorative purposes rainbow corn is a great success.



are the dianthus plants that did not learn to advertise to the bee—and where are the desert cactus plants that could not protect themselves with thorns?

On and on we go, one step backward sometimes, then two steps forward—marking time awhile, then onward with a spurt—the pear tree, the dianthus, the cactus plants, and we—each individual among us a little different from the rest, each with a separate combination of old environment stored within us, finding always an infinity of new environment to bring it out; growing up together, the pear trees, the dianthus, the cactus plants and we, all of us depending on the others, and each of us playing his separate part in the march of adaptation.

On and on we go, because of Infinite Variation.

And so, from whatever viewpoint we approach the study of plants—whether with an eager eye to the future and the past, or whether with an eye, opened only a slit, to see simply the things we can touch and feel, we find evidences of adaptation made possible through variation.

The violet, responding to kindness, became a pansy.

The pear, responding to racial tastes, adapted itself to the Orientals and to us.

Corn, responding to a need for food, produced forty times the kernels which it had produced before.

The orange, the lettuce, the celery, and every cultivated plant that grows, responding to our market demands, have transformed themselves to meet a readier sale.

And those daffodil and narcissus seedlings, how eloquently they tell of the adaptation of a plant to fit an individual ideal!

We studied electricity a long time without much apparent practical benefit. Then suddenly electric lights and trolley cars were everywhere.

We knew the principles of sound vibration for centuries before the telephone and the phonograph appeared, but it took less than a generation to make them universal.

We dreamed motor carriages three hundred years before we got one, and then, in a decade, we awoke to find our dream come true.

And, almost from the beginning, man has studied the forces which go into the make-up of life without much encouragement, till now these ages of contemplation have begun to crystallize into thornless cacti, stoneless plums, fragrant calla lilies and a thousand other results as definite and perhaps even more

fundamentally important to the life and well-being of the human race than the trolley or the telephone or the omnipresent automobile.

Who among us shall say what new plants even a decade now may bring forth?

On and on we go; one step backward, sometimes; then two steps forward; marking time awhile; then onward with a flight.

LET US NOW PRODUCE SOME NEW COLORS IN FLOWERS

Developing Desired Characters in Heredity

An architect, in selecting the materials for his structure, sends for limestone to Bedford, Indiana, or for marble to Carrara, Italy, or for bricks to Haverstraw, N. Y., or for rustic redwood to California.

In the process of turning his blue print into a building, he draws on the whole world—a little here and a little there—for his supplies.

So, in the production of a new plant in which we hope to produce some definite useful results, we must first seek out the materials with which to build.

Only our search will be, not for substance, but a search for *stored-up heredities*—not a search for bricks or stone or lumber, but a search for *living traits.*

The sturdy dandelions in our vacant lots, with their parachutelike seed balls, reveal a structural

CALIFORNIA POPPY

(*Eschscholtzia*)

This direct-color photograph print shows the wild California poppy, so called, golden-yellow, as it grows in this vicinity. This common wild flower covers California's hills and valleys at certain seasons and from it the State is supposed to have received its name "The Land of Fire."

ingenuity and fitness to survive which may have cost ten thousand generations of patient struggle.

The sweetness of our cherries, our grapes, our plums, has been developed only through ages and ages of response to environment, with some environments so oft repeated that they have hardened into heredity.

The flowers on our lawns may have acquired their colors in France, or in Ecuador, or in Siberia; our nuts reflect flavors acquired through a world-wide migration; and even our early vegetables show traits which hark back to times before animals and men came into their lives.

So, just as the earth has stored up limestone in Indiana, and marble in Italy, and brick-clay in New York, and five-thousand-year-old redwoods in California, for the architect to draw upon, just so, in a world full of plants, representing an infinity of ancestry with its infinity of heredity, will we find an infinity of traits with which to build.

If we wish to change the color of a flower, or its fragrance, its size, or its adaptability to climate—if we have it in mind to transform a tree or its fruit, or to give any plant a new trait or a new habit—the most practical way is to accumu-

late and intensify the quality we want out of the mass of heredity about us.

"I thought," says some one, "that plants could be transformed merely by changing the environments in which they grow."

So they can, if time is no object. But the quick and economical way is to take advantage of the combined environments of the past which are at our instant disposal; to short-cut to our result by using well-established traits and thoroughly formed habits, rather than to spend the years or lifetimes which might be necessary to produce new traits and new habits from the beginning.

It is better to seek out, first, what nature has stored away for us, and then to use new environments to improve or intensify traits and habits which already have the advantage of several centuries of start.

It is the same principle of economy which we apply to everything we do.

So long as there is plenty of coal within easy reach it does not pay us to build machines to utilize the energy of the sun's rays or of the ocean tides. And, similarly, so long as there are untold thousands of plants embodying, in some form, almost every conceivable trait we might desire—untold thousands of plants like the cac-

tus, crab apples, or wild potatoes waiting only our attention to make them useful—we can hardly afford to waste time in doing what nature already, laboriously, has done.

The hard part, always, is to make the start.

Those who are late sleepers, for example, know the weeks of discouraging attempts it takes to fix the habit of arising at seven instead of eight, or at six instead of seven. Yet, once we have thoroughly accustomed ourselves to the new hour of awakening, it is just as difficult to get back to the old hour as it was to get away from it.

It is as if the tendencies within us, having accommodated themselves to each other and to our surroundings, cling together tenaciously to maintain the equilibrium between themselves; when we change our surroundings they adjust themselves to the change with difficulty; but once adjusted, hold together as firmly again as they held before.

So in plant life; when we transplant a flower or a tree, it shows signs, in accommodating itself to its new surroundings, of evident distress; it looks sickly, its leaves droop, it gives many outward proofs of the inward struggle which it is undergoing.

As soon, however, as its suddenly scattered tendencies have collected themselves, the plant

A BURBANK BONFIRE

The photograph print here is remarkable in that it is made from a color photograph taken at night of one of our so-called $10,000 bonfires. Such a photograph in even black and white would be extremely difficult of accomplishment.

begins an era of immediate improvement, and does as well or better than it did before transplanting—as well, in fact, as its new surroundings will permit.

If new habits are hard to start, new traits are harder. It is hard to teach a plant to twine when it has never twined before, or to persuade it to be pink when it has always been yellow; just as it is hard to get a boy interested in the study of law when his likes, all his life, have been along the lines of engineering or mechanics.

In the establishment of a new trait, in fact, the whole motion of life must be interrupted, its momentum arrested, the resulting inertia overcome, and new momentum in a new direction gained.

But, if every difficulty has its recompense, we are well repaid for the labor of acquiring or instilling a new trait by the fact that, once acquired, it has a tendency of its own to increase and expand and grow.

The boy who finally gets interested in law, who gets past the point where it becomes an irksome drudgery, begins, at length, to develop a steadfast love for his work so that what was to him, once, a bugbear at last becomes an absorbing ideal.

The cactus, for example, which produced its first spines with difficulty, later became more and more spiny, even though the need for spines had disappeared. Our flowers grow more beautiful, our fruits more luscious as their tendencies gain momentum.

We may take it as a rule, almost, that a habit, once fixed, hardens: that a trait, once established, grows stronger and stronger.

The easiest way, therefore, is to work *with* heredity, and not *against* it—to spend a month searching out a desirable trait or habit, rather than to spend a year or a decade trying to overcome an undesirable one.

And, now, to a practical experiment.

From almost any seed house we may procure the seeds of two African wild flowers. One is the African orange daisy, the other a white daisy of the same family.

The orange daisy is a sun-loving flower, as its beautiful, rich tint clearly testifies.

The white daisy, by its whiteness, shows equally unmistakable evidence of an ancestry which has preferred the shade.

Bright colored flowers are most invariably those which have grown in the sun. White flowers are more often those which bloom at night.

"Because the sun reacts with the soil to produce bright colors, while the shade does not?" I have been asked.

I prefer to believe that insects make the colors. The flowers which grow in the bright light need their brilliance to attract the insects, flowers in the shade are more easily observed if they are light or white in color; it is all a matter of advertising contrast; and, throughout the ages, each particular flower has been striving to perfect a color contrast scheme of its own. It may be that the combination of sun and soil makes possible brighter colors than the combination of shade and soil; but wind-loving plants, like corn and trees, which grow in the sun, do not bedeck themselves in colors—only the flowers which find it necessary to attract the insects.

In practice, at any rate, the color of a flower is one of the reliable guides in the study of its life history.

Taking the orange daisy and its white cousin side by side, we see at once a family resemblance.

The leaf formation, the root formation, the arrangement and the number of rays, the arrangement of stamens and pistils, bespeak the fact that here are two plants more or less closely related; one orange and one white; the white one a little taller, more graceful perhaps, and slightly

THE CALIFORNIA POPPY TURNED CRIMSON

This beautiful variation was produced on my place some twenty-five years ago. Many new shades have been produced here since then, among them one named "Fire Flame," which is an unusual and very pleasing combination of the colors yellow, orange, and crimson.

less hardy; but cousins, beyond doubt, having within them many parallel strains of heredity.

Let us assume, then, that the orange of the orange daisy is the heredity of ages of sunshine and the white of the other daisy is the inheritance of ages of shade; there are other indications in the habits of these plants to verify this conclusion; that both started from the same point, and that one found itself growing in cleared fields, while around the other developed a forest of shade; so that, finally, as environment piled up on environment and accumulated into heredity, each flower became so firmly fixed in its own characteristics as to constitute a species, as man has often chosen to call it, of its own.

If we take the seeds of the African orange daisy, and plant them in the shade, they will still produce orange flowers. That is stored-up heredity. No doubt, if we continued, year after year, to replant them in the shade for a century or so, they would begin to transform themselves to white like the other daisy.

If we plant the white African daisy in the sunshine, it will still give us flowers of white—the heredity of ages overbalancing the pull of immediate environment, and needing a long-continued repetition of environment to balance and finally overcome it; but if we were to keep it in

the sun throughout enough generations it would, no doubt, bear us flowers of brilliant orange.

Here, then, are two divergent strains of heredity in two somewhat closely related species—one orange, one white—one sturdy, one fragile—each strain so thoroughly fixed that in a lifetime it would probably be impossible, through environment alone, to overthrow it.

Let us next take a twenty-foot flower bed; divide it in the middle, plant one side solid with the orange daisies, and the other side solid with white daisies, and let the bees and the breezes combine those heredities to produce a perturbation, through which we hope to secure some new colors.

The breezes and the bees carry the pollen from flower to flower; the rays fall away, and disclose the fertile seed in which, for the first time, these two strains of heredities are combined.

From the millions of seeds which we obtain from these composite flowers there are some with the white tendencies stored away unaltered, some with the orange tendencies still predominant—some with white pulling evenly against orange, some with orange slightly stronger than white, and all with an infinity of variation between.

We shall find in some seeds a combination of tendencies, not only of the two species,

but of the families of the two species, and of the individuals of those families: mixed, upset, disturbed so thoroughly that not only will the life history of both parents be laid bare in the resulting plants, but through the blends new characteristics, probably never seen before, will show themselves.

Here we have taken two plants which, since the beginning, have been storing up traits; each working out its own destiny; each separated from the other, perhaps by a mountain range or a lake, and thus never before brought to a place where those heredities could combine; then in a single season, through combinations, we produce the seed for a new daisy reflecting every conceivable blend of those different heredities.

When we plant this seed the following spring, we shall have pure orange daisies, pure white daisies, perhaps pink ones, yellow ones; daisies large and daisies small; daisies with big black centers, and daisies in which the centers are colored the same as the rays.

We shall find some a deeper orange than the orange daisy because the balance which has determined the established shade of orange has been upset.

We shall find purer whites than the white daisy ever knew—as a result of the combination.

THE CALIFORNIA POPPY TURNING WHITE

A nearly white California poppy is sometimes found growing wild. After several years' selection these produce pure white flowers from seed, and by further selection will "come true" from seed.

We shall find daisies with rays whose color front and back is the same, and daisies with different colors inside and out.

We shall, in short, find all of the old inheritances of the flower and of the combinations of them—all of the colors, shapes, sizes, forms, elements of strength or weakness—uncovered before us.

And between the white and the orange we have but to select the particular flower of our fancy.

If the flower we select, perchance, showed some weakness, or if its tint were a little too light or too dark, or if for any other reason among this infinite color variation we did not find the exact result we sought, another season or still another would surely bring it forth; for next year, instead of planting white and orange, we should plant a selection of our new daisies, and instead of getting a combination of two parentages, we should get a combination of combinations.

Then, having secured the color called for in our original mental blue print, we might find structural improvements to make in the flower—we might want to increase its height or to lengthen the daily period of its opening, or to rearrange its rays into a more chrysanthemum-like form, or to increase or decrease the size of

its center—or to accomplish any one of a number of other ideals which we may have set up for our production.

So on we go, season after season, always selecting, obtaining one this year which bears seeds for next, with the bees and the winds anxious to carry on the work, if we are too lazy or do not have the time; narrowing our lines of heredity down and down until finally some day—maybe fourteen months after the experiment began, or maybe fourteen years, we can say: "Here is a plant such as no man ever saw before—here is the exact plant which we have planned."

"But will the seed of this new daisy," some one asks, "produce more daisies of this same color?"

Of all of the seeds of that daisy there might not be one which would reproduce the color which we have obtained. The seeds of that daisy sown together in a bed may be expected to show as great a variation as the seeds of the white and the orange exhibited when they were first planted after the bees and the winds had done their work.

But there need be no discouragement. By dividing the roots of many plants or raising them from slips or cuttings we can, in a single season, from a single plant, produce a great quantity of

plants — each similar to the original plant, because each, in fact, is a part of the original plant.

But by keeping our new pink daisies together year after year, in perhaps six years or ten or fourteen, pink being crossed with pink, and the equilibrium restored, we should find that we were getting seeds which would come true, or nearly true to type.

We greatly disturb heredity to produce variations; then we select the variation which pleases us and fix it by further selection and repetition.

The architect can always build a second structure better than the first, and the plant improver likewise finds in each experiment a multitude of new suggestions for the production of still other changes and improvements.

In even the handful of daisy variations which can be reproduced here there are to be seen countless new tendencies, any one of which might lead to the perfection of a wholly different, if not a better flower.

There are, of course, the variations in size— and those with the long petals show that with encouragement the flower, simply by quantity production and continued selection, might produce an offspring with blossoms much larger than those of either parent.

"STAR"—CHILEAN WILD FLOWER

Three thousand six hundred varieties of wild flowers have been sent me by one collector in Chile, the major part of which are unnamed and unclassified. Here is one that shows interesting peculiarities of petal that give it distinction anywhere. Also it is beautiful, as a glance at the picture shows.

Some may exhibit a tendency toward doubleness which gives rise to the thought that the new daisy, if desirable, might be made as double as our roses and carnations; in fact, this has already been done.

In other variation it might be noted that some are pink, yellow, or intermediate colors, while others may show deep red or purple streaks on the backs of their rays. From these it might reasonably be expected to produce a daisy having one color within and another color without.

From the bed of seedlings with no two daisies exactly alike, there might be prepared a list of a thousand different tendencies, each susceptible of cultivation, each the possible starting point of some new transformation.

It is only when the life history of a plant, with all of its divergent tendencies, is uncovered in some such way as this, that the plant architect can see the full possibilities of further improvement.

The daisy which we use especially for the purpose of illustrating this chapter may, or may not, be a desirable production—it may or may not repay the thought and effort which it cost—but it shows the simplest method which the plant architect has within his reach—a method which, applied in the same way toward the accomplishment

A BED OF CHINESE PINKS

Here large numbers of the Chinese pinks have been allowed to run riot, that each plant might prove its capacities in competition with its fellows. Each day we go through such a bed, singling out and marking the half dozen or so plants that most fully meet approval.

Or, suppose we have a tree which bears delicious fruit in small quantities.

Let us then find one with a tendency to overproduce, even though its fruit, in size, flavor, and appearance, be inferior.

In some combination between the two, simply by following the leads which those combinations themselves will give, we shall in a few years, very likely, discover one variation which combines the productiveness of one strain of heredity with the deliciousness of another.

Or, perhaps, we have a plant which bears us berries of wonderful flavor, but too small to be marketable.

Let us find a plant with large, beautiful berries, even though they be insipid, and see if, between the two, by matching heredities, there is not to be found some new berry which is luscious, large, and beautiful.

Or, supposing that in our own particular soil there are varieties we should like to grow which fail to prosper, while other less desirable varieties thrive.

Our problem, then, is but the combination of heredities to bring the desirability of one with the hardiness of another into a single new plant which, as it were, we make to order.

SAMPLE OF AN IMPROVED GLADIOLUS

One of the thousands of variations my own work with the gladiolus has brought forth new colors and new combinations of color. The short stalk which makes staking unnecessary was developed on my grounds nearly forty years ago. The thick petals and lasting qualities of the flower originated here. The double gladiolus and the gladiolus which blooms all around the stalk like a hyacinth, first appeared here.

turtiums with their leaves can climb like the monkeys, while other plants can not be forced to climb because there is no climbing heredity within them.

You may try to make corn climb a hop pole, or to make hops grow straight in the air without a pole or string. But in a lifetime you cannot succeed.

It is heredity, heredity, heredity. Environment, unless oft-repeated, only serves to bring heredity out.

The climbing monkeys and the disappointed dog show us an important truth in our work.

If we want to take advantage of a climbing tendency in a plant let us by all means find a plant in whose heredity that climbing tendency is a part. Let us not try to teach monkeys to bark, or dogs to swing from th limbs of trees by their tails; let us not try to make corn climb the hop pole, or hops become shade trees.

Maybe these things could be done. In fact, with unlimited time, there is no question that they could. But with plenty of plants about us with ready-made heredities of which we can avail ourselves in a single season, it would be folly to try to accomplish the same result in a harder way, well knowing that only the thousandth or mil-

lionth generation ahead of us could see the results of our work.

In our search for heredities we shall find many plants which are scarcely worth working with—plants whose environments have not led into heredities which are desirable for our ends.

But at the same time we shall find thousands of plants in the least expected places—which, at first, seem impossible of use—which with a little encouragement yield us rare heredities for our work.

When the masons, carpenters, and decorators have finished the architect's house, and the keys are turned over to the new owner—then, and from that moment, the structure begins to depreciate until it crumbles in decay. The furniture movers dent the stair rails, the children scratch the doors, dust begins to darken and destroy the luster of polished surfaces; and the sun and night, and the frosts and the thaws, rain and the heat, slowly and irresistibly carry the structure on its downward grade.

But when the architect of plants has combined old traits into the production of his ideal, he has fashioned something which, if his work is well done, the suns, and rains, and frosts, and winds will not depreciate; he has produced a living thing which, in spite of discouragements, and

neglect, and abuse, will keep on, and on, and on —*improving as it goes.*

How few, indeed, are the materials which the architect of buildings has at his command when compared with the range of living traits which the architect of plants may call into play!

Our search, then, is a search for stored-up heredities—a search for living traits.

SHORT CUTS INTO THE CENTURIES TO COME

Better Plants Secured By Selective Evolution

"WITH the bees buzzing about in the thousands of blossoms on your experiment farm," said a visitor, "I should think that the plants would get all mixed up; I should think that the daisies would be crossed with carnations, and the carnations with balloon flowers, and the balloon flowers with poppies, and the poppies with cactus."

If we were to watch a bee at work, we should quickly discover one reason why this does not happen—one reason, at least, why cherries, prunes, roses, and geraniums have not long ago been reduced to a scrambled mess.

Our observation of the bee would show that, in going from flower to flower, it goes usually to flowers *of a kind.*

We should see that, if it starts in the morning with clover, it visits no other blossom during the

AT THE DOOR

Even the flowers that grow beside my home are always undergoing observation and being tested as to their capacity for further education. So pictures taken in different seasons do not have the same appearance. At the moment, this beautiful rose has the place of honor as the decoration selected for the porch. This rose is the Corona—a primroselike seedling of Crimson Rambler.

It would seem that much of the ingenuity evident in nature is directed toward a twofold end:

First, toward producing an endless combination of heredities in plants of the same kind—which, to give them a name, we may call crosses.

And second, to prevent the combination of things out of kind—which, to distinguish them from crosses, we may call hybrids.

The first aim insures infinite variation—the mixing up of parallel strains of heredity in such a way that no two living things are exactly alike, and that, in each new balance of tendencies produced, there is the possibility of an improvement.

The second explains why, though all roses differ from each other, yet all are roses—why, though every living thing has its own individuality, its own personality, each bears the unmistakable characteristics of its kind.

"Here and there through nature, nevertheless, are hybrids. Are these accidents—the result of some carelessness, some lapse?"

Everything that is, is a definite part of the Scheme of Things.

We see crossing between kinds and realize its tendency and purpose, and see its value in the Scheme, because it is going on about us always, everywhere—because it is a quick-moving pro-

cess which we can observe without doubt or difficulty.

But when, on the other hand, we see the provisions in nature against crossing out of kind, those numberless ingenious devices designed to prevent the production of hybrids, we have no right to conclude that hybrids are not a part of the Scheme of Things.

They are—else there would be no hybrids.

Crossing between plants of the same kind is a continuous active process necessary to the production of better and better *individuals*.

Crossing out of kind, while more radical, is a process which has just as definite an end as crossing within kinds.

Let us go back to our African daisies.

If we read their history aright, there was, first, an orange flower which grew in the open veldt—a flower which accommodated itself to the peculiarities of the soil and the air in which it grew, and to its plant, insect, and animal neighbors—so that it became a thriving, successful race, each generation a little stronger—each year seeing it increase in numbers and spread in territory. In its spread, we may well imagine that the winds, or the animals, carried its seed over otherwise impassable barriers—just as human environment carries one son to New York to

become a lawyer, another to Pittsburgh to become a steel maker, and another to the gold fields of Nevada.

Thus reaching out, always into new environments, some branch of this daisy family found itself in the midst of a clump of trees,—trees which multiplied and grew till they obscured the sun and left the tiny plants in the obscurity of dense shade.

As the trees grew (and just as slowly, quite likely), the daisies at their feet accommodated themselves to their new environment—they adapted themselves to the shade and moisture—they had less competition, perhaps, from other small plants and so became less sturdy—they changed their color to the one best suited to attract available messengers of reproduction.

At this point we interrupted the evolution of the African daisy by planting the white and the orange together and securing, in the pink one, an immediate blend of their divergent heredities.

But it requires no stretch of the imagination to believe that, had we left them to their course, the same end would have been accomplished a century, or a thousand centuries, from now; that the same migratory tendency which took the white daisies into the woods would, in time, have

THE NEW AMARYLLIS AND ITS PARENTS

Having effected new combinations between species, in the amaryllis, a combination was made between genera. In this direct-color photograph print the improved amaryllis and its tiny parents are shown in exact proportion. The larger one is ten inches across.

into every step of its accomplishment, and it enters into the production of every succeeding plant which represents that accomplishment.

If you believe that nature makes no mistakes, and has no lapses, how can you account for the evident unfitness of so many individual plants to survive—how can you account for the wastefulness and extravagance which is apparent throughout all forms of plant life?

Leaving nature out of it for the moment, let us look at the work which I have been doing here for fifty years. There has hardly been a time during this period when I have had less than twenty-five hundred experiments under way, and there have been seasons when from three to five thousand were in process. Estimating that on this three-acre home tract, considerably more than one hundred thousand definite, separate experiments in plant life have been conducted, in all.

Some of the experiments which have taken the most time and cost the most money have produced no apparent result; and some of the results which seem most important have been achieved in the simplest way, with the least expenditure of effort.

Out of the entire total of experiments tried, there have been not more than a few hundred

which, so far, have resulted in a better fruit, or a better flower, or a more marketable nut, or a more useful plant—that is enough better in all respects to warrant its introduction.

On the other hand, I should feel repaid for all the work I have done if only a dozen of these experiments had turned out to be successes. It is in the very nature of experimentation—we must try many things in order to accomplish a few.

And this is just what is going on in nature all the time—excepting that where we might get one success out of forty failures, there might be but one out of a thousand or a million if the plants were left to work out their own improvement unaided.

Then, after all, the unsuccessful experiments are failures only in a comparative sense.

If you have ever watched the bridge builders constructing a concrete causeway, you must have seen the false construction which was necessary—the stout wooden structure into which the plastic material was poured—a costly structure in itself which was put up only to be torn down.

We cannot call this wooden structure extravagance or waste, because it was a necessary step in the completion of the work. And so, while, in nature, we find many individuals which are

weak—many steps which look like backward steps instead of forward ones—many apparent oversights, yet my own work has shown that this is true, that these are simply elements in a necessary scheme of false construction, without which the final object could not be achieved.

The price of all progress is experiment, and successful experiment is brought about, always, at a terrific expense of individual failures.

But who shall say that progress, any progress, is not worth all its costs?

It is simply by eliminating steps and providing short cuts, and bringing the human mind with its ideals, will, judgment, and persistence into the environment that we are able to produce new colors in a few months when, without our influence, nature might easily have taken till 4020.

The real work before us, then, is to study nature's processes—to learn to read the history of plants, to uncover tendencies and understand their trends—and then to provide short cuts so that the far distant improvement may be made a matter of months, instead of centuries.

These short cuts and their application, from this point on, will be our principal study; perhaps a single illustration here, more comprehen-

MORE THAN FIVE HUNDRED KINDS ON ONE TREE

This direct-color photograph print shows one of my cherry trees which has produced as high as five hundred kinds of cherries at the same time—this for the purpose of convenient comparison and intelligent selection.

sive than that of the daisy, will serve to give a clearer idea of their kind:

Let us take, then, as a specimen, the methods employed in the production of a new cherry.

First, as with the daisy, there must be an ideal —some particular kind of cherry of which we have made a mental blue print. Let us say that our blue print calls for a large, sweet cherry, which will ripen early and bear long —taking into account that appearance is a great factor.

The first step would be to gather in our elements; to pick out a large, beautiful cherry which, after the manner of many large, beautiful fruits, may be more or less insipid in taste; then to select another cherry, size and appearance inconsequential, which has the delightful flavor our plans and specifications call for.

Let us take not one of each of these types, but a number of them, and then when they have bloomed, let us, by hand, cross them back and forth, making in all, we will say, five hundred crosses; each tied with a certain color of string for the purpose of later identification.

The petals of the blossoms which we have crossed will fall away; long stems bearing green cherries will begin to take their place; and

finally the twigs which we have marked with strings will reward us with their ripened fruit.

There is an interesting legend of the French girls who used to take apple boughs in blossom and shake the pollen over the apple flowers of another tree, a legend of the wonderful variation in the apples which they secured.

And here and there in our work we shall see a few exceptions to the general rule, which seem to prove that the French legend perhaps was founded on fact.

These exceptions, which will form the basis of an interesting series of experiments for us later, need have no bearing on our present cherry work.

For, as a matter of practical fact, we shall find no outward evidence of our work. The meat of the five hundred cherries which we have crossed, we can safely assume, will taste the same, and be the same, as though we had let the bees attend to pollination; the cherries that result will not be different in flavor or appearance from the other cherries on the tree.

But inside the stony seed of each of those cherries we shall find an indelible living record of what has been done.

So, disregarding the fruit, we save our five hundred cherry seeds and plant them in a shal-

low box until they have sprouted and then transplant they till they attain a six or eight inch growth.

So far, let us see how we have shortened nature's processes.

In the first place, we have brought together a large, insipid cherry and a homely, small, sweet one, brought them from points, perhaps, two thousand miles apart.

In the natural course, those two cherries would have spread; they would, eventually, have come together, possibly; but we have brought them together without delay. Perhaps, in this, we have saved a thousand years.

In bringing our two kinds of cherries together we have brought not only one of each type, but dozens, or hundreds, each selected for its size, or appearance, or some probable quality which it contains within. In this simple selection of individuals we may have saved other thousands of years.

With unerring accuracy we have seen that the pollen of the two kinds has been interchanged, so that the five hundred or so resulting seeds will represent the two heredities we wish to combine —and only these.

Who can estimate how long it might have taken the bees and the winds, working even in

TWO SEEDLING TYPES OF CHERRIES

They are shown here together, so that their similarities and differences may be seen at a glance. Yellow, pink. red, or purple cherries often come from the seeds of black ones, and these and other colors may come from seeds of any cultivated variety.

neighboring trees, to effect specific crosses with the certainty which we have assured?

Now, with new heredities bundled up in our five hundred cherry stones, we plant them under every favoring condition in our shallow box, and unless mishap or accident intervenes, we get new cherry trees from all, or, at worst, lose but a few.

And now, with our sprouted cherry seedlings six inches or eight in height, with no man knows how many thousand years of nature's processes cut out, we come to one of the most important short cuts of all—quick fruiting, so that there may be quick selection.

Grafting is no new practice.

Virgil wrote verses about it:

> But thou shalt lend
> Grafts of rude arbute unto the walnut tree,
> Shalt bid the unfruitful plane sound apples bear,
> Chestnuts the beech, the ash blow white with the pear,
> And, under the elm, the sow on acorns fare.

Pliny, evidently a much more practical man, within the same century, describes a cleft graft and bespeaks the following precautions: that the stock must be that of a tree suitable for the purpose; that the cleft must be taken from one that is proper for grafting; that the incision must not

be made in a knot; that the graft must be from a tree which is a good bearer, and from a young shoot; that the graft must not be sharpened or pointed while the wind is blowing; that the graft should be inserted during the moon's increase; with the final warning, "A graft should not be used that is too full of sap, no, by Hercules! no more than one that is dry and parched."

"Graft close down to the trunk," the later theory of grafting has been, "there the sap pressure is highest and the grafted cion has the best opportunity to live.

"Graft away out at the tip ends of the tree and you will save from two to seven years of time.

"Grafting close to the trunk gives the cion a better opportunity."

Give anything a good opportunity and it takes its own time to mature.

Take away that opportunity, and responding to the inborn tendency of every living things to reproduce itself, it will hasten the process without waiting to accumulate strength. Therefore, if we graft away out at the tip ends of the tree, while we make it harder for the cions to exist, yet, in consequence, they will bear much sooner.

Furthermore, if we graft close to the trunk, we can, at best, attach but a few cions.

But if we graft out at the tip ends, we can put five hundred or more cions on a single tree.

By grafting the smaller branches, fruit production is greatly hastened, cutting from two to seven years out of the long wait for the fruit which is to tell the story of the heredities which are confined within the seed.

It is possible, at this point, to give but the barest glimpse of the results which this mode of grafting made possible. Under the proper heading, the details will be fully explained, together with a summary of the results of hundreds of thousands of grafts, showing that, while the average time of fruiting has been brought down to less than two seasons, in some exceptional cases fruit has been secured for testing *the same season that the graft was made.*

Here, too, it is not possible to convey more than a general idea of the plans which, in every operation, are aimed toward the end of producing the quickest possible test. Whether it be the quince seedlings bearing fruit the first year or yearling chestnut trees loaded down with nuts; or ten year old walnut trees, the size of their century old cousins—all through this work the plan and the method is to save time for the *individual plant* as well as to provide short cuts for the process of evolution.

SOME OF THE 400 COME TO JUDGMENT

This picture (reduced about one-half) shows ten of the hundred or more varieties of cherries picked on the same day from the same tree, and laid out for examination and selection. As new combinations are effected each season through cross-pollinization, there are always unique varieties to be found on the tree each June time. New varieties, may, of course, be perpetuated by grafting.

To go back to our cherry seedling, now six inches above the ground, if we were to depend on nature's processes, by careful planting and cultivation we might, with care, produce cherries in seven years, but, by the above method, we shall have our cherry crosses in 1920 instead of in 1927—five hundred of them all on a single tree, so that they can be plucked and laid out, first, for a visual selection, to select the ones which conform to our ideas of color, size, and beauty; and, second, for selection through taste—to find the one, or the two, or the dozen among them which come the nearest the ideal of our original mental blue print.

Perhaps of five hundred cherries spread before us none may fit the blue print; or perhaps one or two approximating it may show signs of further improvements which ought to be made.

Eliminate the rest, and start afresh with these two—begin at the very beginning with them again—grow more seedlings, produce quick fruit through grafting, and select again.

Every little while I have, as the neighbors choose to call it, a $10,000 bonfire.

In such a bonfire there might be 499 cherry plants out of the five hundred which we have just made; there would be 19,999 rose bushes

which had been brought to blooming in order to find the twenty thousandth which was not burned —or perhaps twenty thousand rose bushes, the one sought for not having been worth the saving; there would be 1,500 gladiolus bulbs with market value of half a dollar apiece, put in the fire after the one, or the two, or the dozen best among them had been selected; there would be twenty thousand cactus seedlings, representing three to five years of care and watchfulness, but useless now, their duty done. A ten thousand dollar bonfire, indeed, without exaggeration.

The builder of bridges can sell the lumber used in his false construction for seconds; and so I could profitably dispose of the elements of false construction in my work—those millions of seeds and bulbs and cuttings which represent second bests or poorer; but every step in the process excepting those concerning the final result is obliterated with a ruthless hand.

It is better to run the risk of losing a perfected product, through the destruction of the elements which went into it, than to issue forth to the world a lot of second bests which have within them the power of self-perpetuation and multiplication, and which, if we do not destroy them now, will clutter the earth with inferiority or mediocrity.

So we see that, while nature might eventually produce the things which we hasten her to produce, yet the improvements would find themselves in competition with the failures which they cost, the failures outnumbering the improvements, perhaps, a million to one. We see that we not only shorten the process, not only achieve a result out of every thousand failures instead of every ten million, but we give our product the advantage of a better chance to live—we remove from it the necessity of fighting its inferiors for the food, and air, and sunlight which give it life.

This, then, is the story of the making of a new cherry to fit an ideal:

First, selection of the elements; second, combining these elements; third, bringing these combinations to quick bearing; fourth, selecting one out of the five hundred; and then, selection, on and on.

These, after all, are but details in the process—minor details, in fact.

The big element, overtowering them in importance, is selection.

First, the selection of an ideal, then the selection of the elements which are to be blended to achieve it, then the selection of the resultant plant, and after that the selection of better and

better individual plants to bear the fruit which reproduces the original selected ideal.

Everything we do, then, is simply done to facilitate selection.

We produce new plants in enormous quantities, in order that there may be many from which to select; and having selected, we destroy nine hundred and ninety-nine one thousandths of our work.

We strive all the while to produce quick results—to eliminate the long waits and to shorten those that we cannot wholly eliminate—simply so that our selection may be truly comparative—as that of five hundred fruits tasted in a single afternoon, and so that lingering expectancy may not prejudice our judgment, or the result.

It took two thousand years or more to bring about the juicy American pear by unconscious selection—and two thousand years for the Orientals to produce the pear they liked.

Yet, as plant improvement goes, the pear was quick to respond to its environment; other fruit improvements wrought through unconscious selection have taken ten times as long.

On the other hand we see the cherry tree, bearing more than five hundred different kinds of cherries at the same time, cherries produced to compare with a mental blue print less than three

years old — among which one, at least, will be found, which will lead to achievement of the ideal.

And, similarly, in every department of plant life, whether it be in farm plants, garden plants, forest plants, lawn plants, or orchard plants, or whether it be in plants which we grow for their chemical content, or for their fibers, or what— we shall find that it is possible to devise short cuts into the centuries to come, and through combining stored-up heredity with new environment, to hasten evolution to produce for us entirely new plants to meet our own specific desires.

Who shall say that progress is not worth all its costs?

HOW FAR CAN PLANT IMPROVEMENT GO?

THE CROSSROADS—WHERE FACT AND THEORY SEEM TO PART

WHEN I first began this work I was taught that a combination between two varieties of the same species was possible —that I might cross one plum with another plum, for example, to get a new variety—but that the species marked the definite boundary within which I must work. The science of that day was firm in its belief that a seed-bearing, fixed, self-reproductive cross between plants of different species was beyond the pale of possibility.

A little later on, when I succeeded in combining the plum with the apricot, and produced, thereby, a new fruit whose parents were of undeniably different species, the law, or rule, was moved up a peg; and I was told that while it might be possible to effect combinations between different species, yet that must be the limit of

accomplishment; that combinations between the next higher divisions, genera, were beyond the power of man to effect.

Then when I was able, after a time, to take parents of two different genera, like the crinum and the amaryllis, and a score of others which might be mentioned, and to effect successful seed-producing combinations between them, I began to hear less and less about laws and rules.

The fact is that the laws and the rules are too often man-made.

Nature, herself, has no hard and fast mode of procedure. She limits herself to no grooves. She travels to no set schedule.

She proceeds an inch at a time—or a league—moving always, but apparently into an unmapped, uncharted, trackless future.

I like to think of nature's processes as endlessly flowing streams in which varied strains of heredity are ever pouring down through river beds of environment; streams which, for ages, may keep to their channels, but each of which is apt, at any time, to jump its banks and find a different outlet.

Just about the time we decide that one of these streams is fixed and permanent, there is likely to come along a freshet of old heredity, or

a shift in new environment; after which we must rebuild our bridges and revise all our maps.

Since the subject of classification is an important one; and since I have at times upset some man-made laws or theories it may be well, at this point, to take a bird's-eye glimpse over the maps and charts which have been worked out.

With a subject in which the bulk of truth is masked in the obscurity of past ages, and with many men of many minds attacking it from many viewpoints, it is only to be expected that there should be differences of opinion.

But, for the sake of making the explanation clear, we may for the moment overlook minor divergences and view only the main backbone plan which meets with the broadest acceptance. To begin at the beginning, we see first, spread before us, three kingdoms whose boundary lines are well surveyed and whose extent is all-inclusive. These are the mineral, the vegetable, and the animal kingdoms.

Our interest lies now in the vegetable kingdom, which bridges the space between the other two. This kingdom first divides itself into six (perhaps seven) branches, or subkingdoms, called phyla.

The lowest of these subkingdoms includes only those vegetables of the simplest type which re-

produce by splitting themselves into two or more individuals. In this subkingdom live the death-dealing bacteria, which bring about such human diseases as tuberculosis and malaria, or such plant diseases as black rot; and our helpful bacteria, too, which are everywhere helping us to digest our food, and without whose help the higher subkingdoms of plant life could not exist; and other plants of the same grade.

The next subkingdom, higher by a step, includes the yeast which we use to raise our bread, or those microscopic vegetables which turn hop juice into beer, apple juice into cider; and others. Those who prefer to chart seven subkingdoms instead of six, divide this branch into two, making the slime molds a separate phylum.

The next subkingdom, ascending the scale, includes, among others, the mosses and liverworts.

From these it is but a step to the next subkingdom, which includes the ferns—the highest type of flowerless plants, and the *first,* in the ascending scale, to exhibit a complete development of root, stem, and leaf.

The final subkingdom, and the one into which our work principally takes us, embraces those plants which produce seeds.

Taking, then, this latter, the highest subkingdom, we find that it separates into two broad

divisions, called classes, one of which is distinguished by bearing its seeds in inclosed packages called ovaries; the other bearing seeds which are exposed or naked. The first of these classes includes the vast majority of seed-bearing plants; the other including principally those trees, like the pine and the cypress, which bear their seeds in open cones.

Next on our chart we shall find that the class is subdivided into orders. The order represents a collection of related families. As an example, the order *Rosales* is made up of the rose family, the bean family, the cassia family, the mimosa family, and twelve other families closely allied.

Below the order comes the family—a division which is still broadly inclusive; the rose family for example taking in not only the rose itself, but the apple, the blackberry, and sixty-two other plants whose close relationship might not at first be evident.

From the family we next narrow down to the genus—which separates the rose from the apple and the blackberry and gives each its own classification.

Beneath the genus comes the species.

And beneath the species the variety.

We may take it as a safe observation that the simpler the form of life, the less the

SOME HYBRID BLACKBERRY CANES

It is quite possible, from the appearance of the cane of the blackberry at certain stages, to predict the color of the fruit which is later to be borne. The application of this short cut is fully explained under a later heading. The picture opposite shows a range of variation produced by crossing.

tendency toward variation; the more complex, the greater the opportunity for individual differences.

So, in the simpler subkingdoms, and in the more general divisions down to and including the order, the lines of division are more readily differentiated, and the work of classification has been fairly free from differences of opinion.

But as the order breaks up into families, and the family breaks up into genera, and the genus breaks up into species, and the species breaks up into varieties, and variations tend more and more to carry the individual away from its kind, there are to be found dissensions and differences of opinion which could hardly be chronicled in eight full volumes of this size.

Nor is the divergent opinion surprising.

It is said that, of an iceberg floating in the sea, but one-eighth is visible to the surface observer, while seven-eighths of the mass is submerged beneath the water line.

Who, from looking at the one-eighth in view, could be expected to draw an accurate detail picture of the iceberg as a whole?

The vegetable kingdom which presents itself to our vision to-day has been under close scientific observation, at most, but a few hundred years.

It has behind it, who shall say, how many tens of thousands of generations of ancestry which, coming before man, went by unobserved—yet which, under new environment, are continually bursting forth to confuse us.

How can man, with only one ten-thousandth of his subject revealed to him, be expected to make charts or maps which shall withstand onslaught, or be superior to criticism?

For the sake of ready understanding we may, however, summarize plant life into the broad classifications outlined above.

First, the vegetable kingdom, which includes all plants.

Second, the subkingdom or phyla, six or seven in number.

Third, the class, which ranks above an order and below a phylum.

Fourth, the order, which ranks between the class and the family.

Fifth, the family, which ranks below an order but above the genus.

Sixth, the genus, which ranks below a family but above the species.

Seventh, the species, which ranks below a genus and above the variety.

Eighth, the variety, which ranks below a species and above the individual.

Yet with but *one certainty* in the entire scheme of classification—that certainty being the individual itself.

Men may tell us that a plant belongs to one genus or to another, that it is of this species, or of that—or that it is even of a different family than at first we thought—but these, after all, are but theories, built up about the plant by man—theories which serve merely as guideposts in our work.

The plant itself, the *individual plant,* if we but watch it and give it an opportunity, will tell us for itself, beyond dispute or denial, just what manner of plant it is—just what we may hope for it to do.

Next in importance to classifying plants, from a superficial standpoint, is a method of naming them.

When we go to the florist's we ask for roses, or marigolds; when we go to the fruiterer's we talk to him of oranges, and plums, and cherries; when we go to the green grocer we ask for lettuce, or cabbage, or peas; when we select furniture we talk of it as being made of mahogany, or oak, or walnut.

Thus, commonly, we call all forms of plant life by their nicknames—and by their nicknames only do most of us know them.

One reason, likely enough, is that the scientific names of plants are in Latin—for the good reason that the Russian, or Swedish, or Spanish, or American scientist is able to describe his work, thus, in a common language.

In giving a plant its Latin name, no attention is paid to its class, order, or family.

The name of the genus becomes its first name.

The name of the species follows.

And the name of the variety, when given, comes last.

Thus, in writing the scientific name for an apricot, or a plum, or a cherry, we should give first the name of the genus, which, for all of these, is *Prunus.*

If we are to describe, for instance, a cherry of the species *Avium,* we should write, following the name of the genus, the name of the species, as *Prunus Avium.*

And then, if we were to write the name of some particular improvement in that species of cherry, we should follow the names of the genus and species with the name of that variety, as *Prunus Avium Mayduke.*

Or, if we were to prepare a technical article about this species, we should write *Prunus Avium* at the first mention of it, and contract it to *P. Avium* when mentioning it thereafter.

In this work, in order to gain clearness with the least effort, and to avoid confusion through the use of disputed terms, it has been decided, so far as possible, to call plants by their commonest names; going, wherever necessary, into a brief explanation in order to identify the plant clearly in the mind of the reader.

Our work is to be a practical work, and the effort which it would cost to master thousands of Latin names might, it is believed, be better expended in a study of the principles and the practice.

There arises, unfortunately, a confusion through use of common names. The California poppy, for example, is not a poppy at all; but for the purposes of this work it has been deemed best to call it the California poppy, by which name it is generally known, rather than to refer to it as *Eschscholtzia;* and so on throughout the list of other plants.

No common name is used, however, which is not to be found in the dictionary; so that those whose scientific interest is uppermost have but to refer to their Webster, which gives a greater wealth of detail than could be hoped for in a glossary or an appendix to these volumes.

A few years after I came to Santa Rosa, I was invited to hear a new minister preach on a

subject which, I was assured, would be of interest to me.

I was not in the habit of attending that church, so I tried to find my way to an unobtrusive seat in the rear, where I could disturb no one. But, as if by prearrangement, the usher would not have it that way—I was led to the front center, where I was given a pew to myself.

As soon as the sermon began, I saw the reason for it all. That preacher, with a zeal in his heart—or perhaps better in his head—worthy of a better cause, had evidently planned a sermon for my own particular benefit. He was determined to show me the error of my ways.

He began by describing "God's complete arrangements," as evidenced in the plants about us, and rebuked me openly for trying to improve on the creations of Omnipotence. He held me to ridicule as one who believed he could improve perfection; he predicted dire punishment for attempting to thwart nature and tried to persuade me, before that audience, to leave God's plants alone.

Poor man! Whatever may have been thought of his good taste, or his tact, or his judgment, I could hardly take offense at his sentiments—for they really reflected the thought of that day.

He could not see that our plants are what they are because they have grown up with the birds, and the bees, and the winds to help them; and that now, after all these centuries of uphill struggle, man has been given to them as a partner to free them from weakness and open new doors of opportunity.

He could not see that all of us, the birds, and the bees, and the flowers, and we, ourselves, are a part of the same onward-moving procession, each helping the other to better things; nor could many others of his time see it.

And the botanists of that day, less than four short decades ago, found their chief work in the study and classification of dried and shriveled plant mummies, whose souls had fled—rather than in the living, breathing forms, revealing their life histories.

They counted the stamens of a dried flower without looking for the causes for those stamens; they measured and surveyed the length and breadth of truth with never a thought of its depth—they charted its surface, as if never realizing that it was a thing of three dimensions.

And that is why those who had devoted their lifetimes to counting stamens and classifying shapes told me, through their writings, that a cross might be made within species, but never

between species; that is why when I did make a cross between species they looked no further into the truth, but simply moved up a notch, and said, "Very well, but you cannot make a cross between genera"; that is why, when I did that very thing, not once, but several times, that type of scientist lost interest in rule making and went back to stamen counting.

To realize the point more clearly, let us observe for a moment the common tomato—which belongs to that large division of plants, the *Solanum* family.

Just as the rose family includes not only the rose, but the apple and the blackberry and hundreds of other plants, so the *Solanum* family includes seventy-five genera and more than eighteen hundred species.

The classification is built around structural facts, such as that plants of this family originally had alternate leaves with five stamens and a two-celled ovary, or egg chamber, each cell containing many eggs.

These structural similarities in the plants of this family trace back to a common parentage and fully justify the classification of these seventy-five genera in a single family.

If we were to look not at the structure, however, but at the seventy-five genera themselves

then, and only then, could we fully realize the wonders which environment, blending with that common heredity within the plant, has wrought.

We should see, among the seventy-five brothers and sisters of that family, if they were spread before us, the poisonous bittersweet, and the humble but indispensable potato; the egg plant and the Jerusalem cherry; the horse nettle and the jimson weed; the tobacco plant and the beautiful petunia; and the tomato itself.

We should see seventy-five plants with original structural similarities, yet differing, in every other way, as night differs from day; and we should be able to trace, if we observed closely enough, the points at which, in the history of this family, new environment, oft repeated, has hardened into heredity, subject to the call of still new environment, which has not been lacking to bring it out; we should be able to trace, by easy stages, why one branch ran to the poisonous bittersweet, another to the potato with its food product below the ground, another to the tomato with its tempting fruit displayed on the vines above; another to tobacco, valued for its chemical content—and so on throughout all of the variations.

VARIATIONS IN WALNUTS

The variations here shown were secured by crossing. In this walnut work nuts are grown by the wagonload for the purpose of finding one or two varieties which may approach the ideal desired.

The tomato, we should see, was the last of the family to fall into a violent change of environment.

A tropical plant, bearing fruits about the size of a hickory nut and not believed to be edible, the tomato found its way into the United States within the past century.

At first, the tomato plant was prized merely as an ornament; it was grown as we now grow rose bushes, and the fruit was looked upon as a mantel decoration until, by accident, it was discovered to be edible. There are, in fact, many such ornamentals to-day which might bear us edible fruit. One in particular, the passion flower, will form the subject of an interesting description later on.

Following the discovery that the tomato was edible came the same course of unconscious selection that falls to the lot of every useful plant. The finest tomatoes were saved and cultivated.

In the environment of the tropics, the tomato fruit of hickory nut size was ideal; it cost less effort to produce than a larger tomato; it contained sufficient seeds to insure reproduction.

But with the advent of man into its environment, its seed chambers increased in number, the meat surrounding the seeds increased greatly in quantity and improved in quality; so that in

virtually half a century the large, luscious, juicy tomato we now know is universally to be found in our markets, in season and out.

No man can say how many thousands or tens of thousands of years it took wild environment to separate the tomato from the seventy-four others of its family. Yet, in less than half a century, see what changes man, as an element of environment, has worked!

We take the seeds of our Ponderosa tomatoes, and midsummer brings us new Ponderosas—so well have we succeeded in fixing the traits we desire.

But were we to take those same seeds to the tropics and plant them under the conditions of only fifty years ago an entirely different thing would happen.

The first generation would be Ponderosas, more or less like those we grow here.

But in the second generation, or, at latest, the third, the seeds of those very Ponderosas, when planted, would grow into vines which bear the old type of tomato—the size of a hickory nut—an immediate response, almost, to the wild tropical environment which prevailed before man began its culture.

From the botanists of only a century ago, examining only dead tomato blossoms from the

tropics, and dried tomato fruits the size of hickory nuts—how could we expect an inkling, even, of what the tomato with less than half a century of cultivation could become?

How short, indeed, the time which environment requires to transform a plant beyond recognition—especially when man, either consciously or unconsciously, becomes a part of that environment!

And, knowing what the Orientals did to the pear, what the American Indian did to corn, what we have done to the tomato, can we not see that while stamen counting has its place, yet, for real achievement in plant improvement, we must look for help not so much to the stamen counters as to the plants themselves as new environment brings their old heredities into view.

How far, then, can plant combination be carried? Is it possible to go above the genus and make combinations between families? Or to go above the family and make combinations between the orders? Or to go above the orders and make combinations between the classes? Or to go above the classes and make combinations between the kingdoms?

The limitations of our work are not generally limitations imposed by nature; they are limitations imposed by the clock and the calendar.

Here we are, pitting ten thousand years of hardened heredity against five or ten years of new environment; sometimes we succeed. Is it any wonder that more often we fail? In five years, however, we can often work a practical transformation.

Every season we are working changes which nature would take ages to work; but from a practical standpoint we must seek always to take advantage of the old heredities which nature has stored up—to make them serve our ends, because this can be done quickly; rather than to create and fix new heredities which might take so long as to rob our work of its usefulness.

Before us is a world of living, onward marching plants which have made, are making, and will continue to make their own rules as they go along. Here before us, too, is the propaganda of our subject with its maps, plans, charts, rules, laws, theories, beliefs, built up all too fixedly, too arbitrarily, too superficially, perhaps, but very completely, nevertheless, around this onward-marching mass.

Let us use to the utmost all the help that science can give; to save time, let us accept the laws and the rules, let us have confidence in the maps and the charts, until the *plants themselves* show our error.

Let us search always, at least for present practical use, for stored-up heredities; just as we would seek stored-up diamonds, or gold, or coal, instead of trying, by chemistry, to produce them.

Great results are possible with time, but let us seek all the short cuts we can.

For, after all, we have so little of time!

With time as our limiting factor, then, we shall find in plant work many things which we cannot hope to accomplish.

We shall find plants, of course, of different species, and different genera—as now classified—a surprising number, in spite of the old belief, which will combine readily to produce fertile offspring constituting a new species or a new genus.

We shall find plants of different species or genera which combine to make a sterile offspring—a mule among plants.

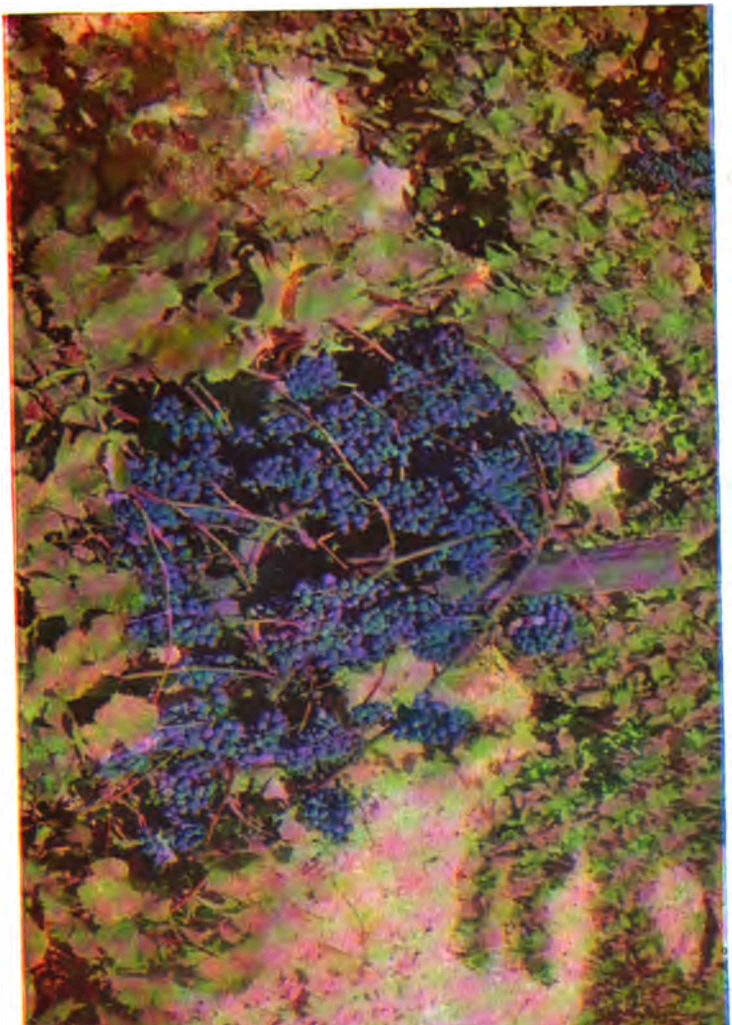
And we shall find plants which can hardly be combined at all—plants in which the pollen of one seems to act as a definite poison on the other—and plants which, through long fixed heredity, seem as averse to combination as oil seems averse to combining with water.

But no man can tell until he has tried—tried not once, but a few thousand times perhaps.

"What is that?" asked a seedsman who was visiting Santa Rosa.

A HEAVY-BEARING SEEDLING

This complex hybrid bears large bunches of grapes of uniform size and in enormous profusion. It has all the qualities of an ideal grape, for the fruit also is supremely delicious.



"That is a *Nicotunia,* and you are the first man in the world who has ever seen one. It is the name which I have given to a new race of plants produced by crossing the large flowering *Nicotiana,* or tobacco plants, with petunias. It is, as you can see, a cross between two genera of the nightshade family."

"H'm!" said the seedsman.

You know the secret now, but if you think that you can produce these *Nicotunia* as you would hybrid petunias, or crossbred primroses, go ahead and try; there is no patent on their manufacture; but if the five hundredth cross succeeds, under the best conditions obtainable, you will surely be very successful. I do not fear any immediate competition.

Perhaps those who have said that species could not be combined with species, or genus with genus, have tried only once or twice or a dozen times. Perhaps patience and persistence as well as a wider knowledge account for some of the upset laws.

"Why not content ourselves to work within varieties as the bees work?" asks some one.

Because by going out of the varieties and combining, we multiply almost infinitely the combinations of old heredities which we may bring into play—we lessen the work which we have to

make environment do by spreading before us more combinations of heredity—we accomplish in two years what otherwise might take two lifetimes.

We see that the science of plant life is not yet an exact science, like mathematics, in which two and two always equals four. It is not a science in which the definite answers to specific problems can be found in any book.

It is a science which involves endless experimenting—endless seeking after better and better results.

Theories are good, because if we do not permit them to mislead us, they may save us time; laws, and maps, and charts, and diagrams—systems of classification and of nomenclature—all these are good, because, if they are faulty, they still reveal to us the viewpoint of some one who, with diligence, has devoted himself to a single phase, at least, of a complex subject.

But we must remember that the theories, most of them, are built around *dead* plants.

While the facts we are to use are to be gathered from *living* ones.

So, every once in a while, when we come to a crossroads where that kind of theory and this kind of fact seem to part, let us stick to the thing which the living plant tells us, and assume that

evolution, or improvement, or progress, or whatever we choose to call it, has stolen another lap on the plant historians.

And let us remember that the fact that ours is not an exact science, with fixed answers to its problems, is more than made up for by the compensating fact that there seems to be no limit to the perfection to which plant achievements may be carried—no impassable barrier, apparently (save time—which limits us all, in everything), beyond which our experiments may not go.

Nature did not make the laws; she limits herself to no grooves; she travels to no set schedule.

MARVELOUS POSSIBILITIES IN THE IMPROVEMENT OF PLANTS

General Survey of Some of the Immediate Improvements Needed.

"I HAVE finished making an analysis of a number of your fruits," wrote a chemist, "and I find that tannic acid, which no one likes in their fruits, vegetables, nuts, or other food, and which prevents many people from enjoying raw fruit, is almost entirely absent in every case."

There are other acids, however, which are beautifully blended with grape sugars and other sweet substances and flavors which make our fruits so delightful and so valuable for food. Would it be a small achievement to rebuild our fruits, grains and vegetables so as to add to the health, happiness, and advancement of the human race?

Such a transformation is one which might easily be wrought in a few years through simple

selection, and serves, here, to illustrate the vast range of possibilities in plant improvement which only await willing hands and active minds to turn them into realization.

Immediate possibilities for plant improvement outnumber the improvements which have already been wrought, a thousand to one.

It is planned in these books to treat of the possibilities of some of the plants separately, in connection with the description of the work which has already been done, since each of these improvements not only suggests the road to countless other improvements which one has not had time to take up, but indicates, in a measure, the method by which their accomplishment may be brought about.

It may be well, at this point, however, to survey, roughly, the range of possibilities for improvement, so that, as we go along, we may have an appreciative eye for the better valuation of the things which are awaiting accomplishment.

The elimination of tannic acid through experimentation for other purposes is but one of the many improvements which have been brought to our attention.

Possibly as striking an illustration of this as could be chosen is one which made itself evident in the plumcot.

So intent was I in the purpose of combining these two species, the plun and the apricot—a fruit which should reflect its double parentage in flesh and flavor—that I thought it best to ignore some of the incidental possibilities of such a combination.

The cross having been made, however, much thought was given to the study of other new characters which the combination afforded.

Some of these were recognized as being of little practical value, others of great importance. The foliage of the plumcot tree, for example, does not necessarily resemble either the plum or the apricot, being quite generally intermediate, but it may be noted in passing that the foliage of a cross or hybrid often takes on the characteristics of either one parent or the other, or may consist of intermediate leaves, or may even present leaves of two distinct kinds on the same individual plant, but often bearing a close resemblance to one or the other of the parents, especially in the second and succeeding generations.

The plumcot foliage being a blend, it was not surprising to discover that the root of the plumcot tree resembled in color neither the bright red of the apricot, nor the pale yellow of the plum, but was of an intermediate shade.

Of the thousands of characteristics of the parent species as they were subjected to examination and analysis, one of the most startling was found in the surface texture of the fruit itself—one of the most novel effects, in fact, to be seen in nature.

The apricot has a fine velvety skin which serves not only as a protection to the fruit from insects and from the sun's rays, but which adds greatly to its attractive appearance.

Plums, on the contrary, always have a smooth skin, and are often overspread with a delicate white or bluish bloom, powdery in form and easily defaced by the slightest handling. This bloom adds a touch of delicacy and beauty to the fruit, suggests its freshness and intensifies the attractiveness of the colors underneath.

In the first plumcots it was noticed that many had a softer, more velvety skin than the apricot and that this persisted after much handling. Then, as the characteristics began to become more fixed, after several generations of plumcots had appeared, it was noticed that the new fruit not only had the attractive velvety skin of the apricot, but that this velvet overspread and protected a bloom like that of the plum, giving the plumcot the plum's delicacy of appearance with

the apricot's ability to stand handling without injury.

When this blend of bloom and velvet was noted, experiments were made to determine how much handling it would withstand. A dozen plumcots were passed around from hand to hand many times, and then left to fully ripen and decay, the condition of the velvet bloom being noted from time to time. While there was a slight decrease in the brilliancy of the bloom, yet it persisted to a surprising degree, even after the flesh of the plumcot had decayed.

The value of this characteristic is greater than might at first be supposed. Plums lose their bloom to a great extent, even on the tree, by brushing of leaves or chafing together. Wherever foliage or other fruit touches it, the bloom is injured or destroyed. It is of course impossible to market the plum without destroying the greater part of the bloom, thus giving the fruit a shiny appearance. In making the photographs in these books, in fact, it has been found difficult, first to find a plum fruit of any variety which has a perfect bloom on the tree; and second, to get the plum in front of the camera without defacing it. Wherever a finger touches the plum, a mark is left, and since fruits, at best, must receive much handling from the orchard to the

THE PLUM'S PERISHABLE BLOOM

From this direct-color photograph print the result of handling plums may be imagined. These plums have been defaced merely by the swishing of the branches of the tree on which they grew. Since the bloom suggests the freshness of the fruit, its perishability is a great drawback in handling and shipping plums to the market. The plum-cots are not defaced by handling.

ultimate consumer, the plum is likely to lose one of its most attractive charms long before its real freshness or flavor has begun to depreciate.

With many of the plumcots, however, the velvety bloom remains through growing, picking, sorting, shipping, handling, and sale. Which means, of course, that the grower, the shipper and dealer receive a better profit, and the consumer gladly pays the extra cost, because appearance, after all, is nearly as valuable a point in a fruit as size, flavor, or quality. This one improvement in the plumcot greatly increases the earning capacity of the fruit, which is simply another evidence of the importance, in plant improvement (and elsewhere), of things which, at first, we are too apt to regard as trifles.

It is the seeming trifles, after all, which appear to have the greatest effect on prices and profits.

Of two samples of canned asparagus one may command more than twice the retail price of the other, and also bring perhaps nearly double the profit to the grower, simply because of the trifle that one variety of asparagus holds its form and color through all the operations from the garden to the table, while the other, dark colored or broken in structure, presents an unappetizing appearance when served, and since it costs no more to raise the best asaparagus, after the ex-

pense of a few seasons of selection has been paid for, what excuse can there be for producing the other kind?

It would be impossible here to begin to catalog the improvements which can be wrought—improvements in size, shape, color, texture, juiciness, flavor, sweetness, or chemical content of fruits; improvements in the appearance, tenderness, taste, cooking qualities, and nutritive elements in vegetables; improvements in length and strength of fiber in cotton, flax, hemp, and in many other textile plants; improvements in the quantity and quality and color of grains; improvements in amount and value of the chemical content of sugar beets, sorghum, coffee, tea, and all other plants which are raised for their extracts; improvements in the stalks of corn, even, so that, though we could make it bear no more kernels, or no more ears, it would still yield us a better forage crop; or better quality and greater productiveness of its special products: starch, gluten, oil, sugar, etc.; improvements, all of them, which are capable of turning losses into profits, and of multiplying profits, instead of merely adding to them by single per cents.

Improving the yield, and consequently the usefulness and profit of existing plants, however, is but the beginning of the work before us.

An almost equally rich field lies in saving plants from their own extravagances, thereby increasing the yield.

The fruit trees of our fathers and mothers were shade trees in size, with all too little fruit.

The ideal orchard of to-day, generally speaking, is one from which the fruit can be picked without the use of a ladder. Thus, already, we have taught fruit-bearing plants economy—saved them the extravagance of making unnecessary wood, at the expense of fruit, since it is their fruit, not wood, which we desire.

The grapes of our childhood grew sparsely on climbing vines which covered our arbors; while the grapes grown for profit to-day grow thickly, almost solidly, on shorter, more compact vines. The value of the vine lies in the fruit and not in the wood.

In so many different ways can we save our plants extravagance and increase their useful products by curbing their useless ones, that it would not be even possible to list them here. But, aside from these, and in the same category, there are countless other improvements to be wrought. The stoneless plum, the seedless grape, orange, lemon and others point the way to a new world of fruits in which the stony or shell-like covering

of the seeds has been bred away. Wild pineapple fruits are crowded with seeds, but who has seen seeds in our cultivated ones? Yet the packers of pineapple in the Hawaiian Islands tell me that about one in a million of the cultivated ones are found containing large quantities of seed—a reversion to the wild type.

Seedless raspberries, blackberries, gooseberries, currants, with the energy saved, reinvested in added size or better flavor, call for some one to bring them about. Grapes more or less seedless we have had for a hundred years or more, and one seedless orange has been known for half a century and the seedless banana has been known perhaps for a thousand years, while all wild bananas are half filled with large, black, hard, bulletlike seeds. Seedless figs, even might be produced, but these could be counted as no improvement, for the oily seeds of the fig give the fruit a part of its flavor.

Thornless blackberries and spineless cactus are productions of priceless value, as is being abundantly proven. Many other thornless plants are to come shortly. Why thorns at all in the world of useful plants, when useful plants no longer need them? They are as expensive and useless as horned cattle, which are everywhere being replaced by hornless ones.

Whatever plant we observe we shall see some waste which might be eliminated, some weakness which might be overcome, some extravagance which might be checked—and all for the profit of producer and consumer alike, as well as the whole world at large.

Still another important department of plant improvement lies in fitting plants to meet specific conditions.

The grape growers of France, Spain, and California, for example, had their fair vineyards destroyed by a little plant root louse (*Phylloxera*), a pest which renders the vine useless or kills it outright. The growers found relief through grafting their vines on phylloxera resistant roots which past environment had armored against this pest.

When we think of the cactus, sagebrush and the desert euphorbia, and of the conditions which, unaided, they have withstood and the enemies which they have overcome, does it not seem as if, with our help, we should be able to produce new races of plants to withstand the boll weevil, the codling moth, and the San José scale; and with complaints so broadcast and successes so marked and so many, does not the production of disease-and-pest-resisting varieties seem an important field for work?

Nor are the insects and fungous diseases the only enemies which plants can be taught to overcome. Trees have been trained to bloom later in the season so as to avoid the late spring frosts which might nip their buds; and to bear earlier, that their fruit may be gathered before the early frosts of fall have come to destroy. The gladiolus has been encouraged to rearrange its blossoms, shorten its stalk and thicken its petals, so that the hot sunshine and the wind no longer ruins its beauty.

And the prune, which at times must lie on the ground till it is gathered or even cured, had the habit, here in California, of ripening about the time of the equinoctial rains of fall. It has been helped to shift its bearing season earlier, so that, now, when the rains come, some of the newer prunes have been cured and are under cover.

In all of these enemies of plant life: insects, fungous diseases, rains, winds, frosts, snows, and the parching heat of the plains, there are opportunities for great improvement in plants, trees, grasses, grains, and flowers.

Yet these enemies form the least important, perhaps, of the special conditions to which plants may be accommodated.

The market demand, for example, is a specific condition which well repays any effort expended in transforming plants to meet.

The grower of early cherries, early asparagus, early corn and every fruit and food which can be offered before the season of more abundant production commences, is rewarded with a better price, which means a larger profit to the producer.

The early bearers, too, may be supplanted with those still earlier, until the extra early ones come soon after the extra late ones, thus filling out the whole year. We now have strawberries which, in climates where there is no frost severe enough to prevent, bear the year around.

The Crimson Winter Rhubarb, another year-around bearer, is an improvement which shows what can be done in the way of meeting market demands.

Cherries of my Early Burbank brought $3.10 a pound wholesale, because of their sweetness and extreme earliness. This may give an idea of the profit of changing the bearing periods of our plants as against taking their product as it comes.

Besides the market demand for fresh fruits and vegetables ahead of the usual time, there is

an almost equally great demand in larger quantities, later on in the season, from the canners and for drying.

The illustration of the asparagus which stands canning as against asparagus which does not, typifies the needs of this demand. The same truth applies to tree fruits and berries and vegetables—to everything that undergoes the preserving process.

Some plants are more profitable when their bearing season is lengthened as much as possible; some, as has been seen, when it is made earlier or later; but we faced a different condition when we produced the Empson pea.

The canners wanted a very small sweet green pea to imitate the French one which was so much in demand. Quite a little problem in chemistry was involved. Peas half grown are sweeter than peas full grown, because, toward the end, their sugar begins to go a step further and turn into starch. With these demands in mind, we planted and selected; planted again and reselected until we had the desired qualities in a pea of the right size when half ripe.

Still another element entered—peas for canning should ripen all at one time and not straggle out over a week or two. The reason for this being that, if they ripen all at once, they may

be harvested by machinery so that the cost of handling is cut to the minimum.

We took the peas which we had selected for form, size, color, taste, content, and productiveness, and out of thousands obtained perhaps a few hundred peas which were planted separately. These, then, were harvested by separately counting the pods and counting the peas, until finally there was combined in this selection not only the best of the lot, but those which ripened all at the same time—practically on the same day. To-day the Burbank Empson peas form one of the chief industries of a large community.

This contract was made to be fulfilled in six years, but as two crops of peas can be ripened each season the desired production was ready and completed in three years.

There are countless other requirements which can be equally well met—little economies which can be taught to the plants — little, as applied to any specific plants, but tremendous in the aggregate.

The list could be extended almost endlessly; the skin of a plum was thickened so as to enable it to be shipped from Cecil Rhodes's farm in South Africa, by way of the Isthmus of Suez to England, then to New York, with some delays, then to California, arriving in good condition.

This was one of my first efforts in producing a good shipping plum; even better shippers have been produced on my grounds and are shipped out of this State by the million crates annually.

Under the head of saving a plant from its own extravagance might well come the large subject of bringing trees to early fruiting, or of greatly shortening the period from seed to maturity in shade and lumber trees. The rapid-growing walnut, and pineapple quince, and chestnut seedlings bearing at six months from the seed stand forth as strong encouragement to those who would take up this line.

And there is the broad subject of adapting plants to special localities. The hop crop of California, the cabbage crop near Racine, Wisconsin, the celery crop near Kalamazoo, the cantaloupe crop at Rocky Ford and Imperial Valley and the seed farms of California—all of these bear eloquent testimony to the profit of a specialty properly introduced.

Who can say how many who are making only a living out of corn or wheat, simply because they are in corn or wheat localities, could not fit some special plant to their thin or worn-out soil?

And who, seeing that some forms of plant life not only exist, but thrive, under the most adverse conditions, shall say that there is any poor land

anywhere? Is it not the fact that poor land often means that the plants have been poorly chosen for it, or poorly adapted to it?

These are all problems which will be treated in their proper places, and which offer rich rewards to plant improvers of skill and patience.

So far, in mentioning some of these opportunities for plant improvement, we have referred only to the betterment of plants now under cultivation.

When we remember that every useful plant which now grows to serve us was once a wild plant, and when we begin to check over the list of those wild plants which have not yet been improved, the possibilities are almost staggering.

Not all plants, of course, are worth working with—not all have within them heredities which could profitably be brought forth—combined and intensified. But, as a safe comparison, it might be stated that the proportion between present useful plants and those yet wild which can be made useful, is at least as great as or greater than the proportion between the coal which has already been mined and the coal which is still stored in the ground.

Greater, by probably a hundred times, for while we have depleted our coal supply, our

plants have been multiplying not only in number, but in kind and in form.

Moreover, from our wild plants, we may not only obtain new products but new vigor, new hardiness, new adaptive powers, and endless other desirable new qualities for our cultivated plants.

All of these things are as immediate in possibilities and consequences as transcontinental railroads were fifty years ago. All can be made to come about with such apparent ease that future generations will take them as a matter of course.

Yet we have not touched, so far, on the most interesting field in plant improvement—the production, through crossing, hybridizing, and selection, of wholly new plants to meet entirely new demands.

Who shall produce some plant—and there are plenty of suggestions toward this end—which shall utilize cheap land to give the world its supply of wood pulp for paper making, the demand for which has already eaten up the larger part of our forests and is fast encroaching on Canada's?

Who shall say that within twenty years there will not be some new plant better than flax, some plant which, unlike flax for this purpose, can be grown in the United States, to supply us

with a fabric as cheap as cotton, but as fine and durable as linen?

Who will be the one to produce a plant which shall yield us cheaper rubber—a plant growing, perhaps, on the deserts, which shall make the cost of motor-car tires seem only an insignificant item in upkeep?

And who, on those same deserts, and growing, perhaps, side by side, shall perfect a plant which can be transformed into cheap alcohol for the motors themselves?

We see that the opportunities for plant improvement broadly divide themselves into four classes.

First, improving the quality of the product of existing plants.

Second, saving plants from their own extravagance, thereby increasing their yield.

Third, fitting plants more closely to specific conditions of soil, climate, and locality.

And fourth, transforming wild plants and developing entirely new ones to take care of new wants which are growing with surprising rapidity.

The cost and the quality of everything that we eat and wear depends on this work of plant improvement.

The beefsteak for which we are paying an ever-increasing price represents, after all, so

many blades of grass, so much grain, or perhaps, so many slabs of cactus; while the potatoes, lettuce, and coffee which go with it come out of the ground direct.

Our clothing is from cotton or flax, or perhaps a sprinkling of wool, or from the mulberry tree on which the silkworm feeds.

Our shoes and our woolens, like our steaks, resolve themselves into grass.

The mineral kingdom supplies the least of our needs; and the animal kingdom is wholly dependent on the vegetable kingdom.

Who can predict the result when the inventive genius of young America is turned toward this, the greatest of all fields of invention, as it is now turned toward mechanics and electricity? This important line of effort would probably have been more enticing if patents could be obtained for meritorious plant inventions, but so far no protection whatever can be extended, even though the new self-repeating products were worth, as some of them are, a thousand million dollars each.

PIECING THE FRAGMENTS OF A MOTION-PICTURE FILM

WE STOP TO TAKE A BACKWARD GLANCE

"WHEN you speak of environment as an active influence," I am asked, "do you mean the soil, the rainfall and the climate?"

Yes, I mean these, but not only these; I mean also such elements of environment as the Union Pacific Railroad.

I will explain.

Go out into the woods, almost anywhere in the United States, and hunt up a wild plum tree, and you will find that it bears a poor little fruit with a big stone.

The only purpose which the wild plum has in surrounding its seed with a fruit anyway is to attract man and the animals, so that they may carry it away from the foot of the parent tree and start it in new surroundings for the good of itself and offspring in the race for life. It

takes very little meat and very little in the way of attractive appearance to accomplish this purpose; and besides, the wild plum has to put so much of its vitality into stone, in order to protect the seed within from the sharp teeth of the animals which carry it away, that it has little energy and no reasonable object left for devoting itself to still further enhanced beauty and flavor.

Now, take the same wild plum after it has been brought under cultivation and as it grows in the average garden and you will find a transformation—less stone, more meat, better flavor, finer aroma, more regular shape, brighter colors.

This, however, represents but the first stage in the progress of the plum; with all this improvement the garden plum still may not be useful for any commercial purpose, because people with plum trees in their orchards are likely to eat the fruit off the tree, or to give it to their neighbors, or to cook and preserve it as soon as ripe. So even the cultivated garden plum may be perfectly satisfactory for its purpose without having those keeping qualities necessary to a commercial fruit.

And this is the point at which the Union Pacific Railroad entered into its environment—

at least into the environment of the California plums.

The railroad became a factor in plum improvement by bringing millions of plum-hungry Easterners within reach by affording quick and economical shipping facilities where there had been no shipping facilities before.

Much as the time of transcontinental travel was reduced, the garden plum could not withstand the journey. With an eager market as an incentive, however, made possible through the railroad, we began to select plums for shipment, until the plum graduated from its garden environment and became the basis of a great thriving and constantly increasing industry. The railroad, by bringing customers within reach of those who had plums which would stand shipment, and charging as much to ship poor plums as good plums, encouraged selection not only for shipping plums, but toward a better and better quality of fruit which doubtless, in the absence of the market which the railroad provided, would never have been produced.

Thus we see three important stages in the transformation of the plum:

First—the wild era.

Second—the garden era.

Third—the orchard and railroad era.

When we stop to think of it, all of the great improvements in plant life have been wrought within the railroad era.

Yet our plants go back, who knows how many tens of thousands of generations?

It took the plum tree all of these uncounted ages, in which it had only wild environment, to produce the poor little fruit which we find growing in the woods.

It took only two or three short centuries of care and half-hearted selection to bring about the improvement which is evidenced in the common backyard plum.

And it took less than a generation, after the railroads came, to work all of the real wonders which we see in this fruit to-day.

Up to two or three human generations ago, the plants, with their start of tens of thousands of generations, were abreast of or ahead of human needs. But human inventive genius, going ahead hundreds or thousands of years at a jump, bringing with it organization and specialization, has changed all of that.

In our race across the untracked plains before us we have outrun our plants. That is all. And, having outrun them, we must lend a hand to bring them up with us if they are to meet our requirements.

Shall we content ourselves with watering our plants when they are dry and enriching the soil when it is worn out? Shall we be satisfied merely to be good gardeners?

Or shall we study the living forces within the plants themselves and let them teach us how to work real transformations?

It is conceivable that a manufacturer of machinery might become successful, or even rise to be the foremost manufacturer in his line, without giving a moment of consideration to the atom structure of the iron which he works—with never a thought of the forces which nature has employed in creating the substance we call iron ore.

It is conceivable that one might become a good cook—a master chef, even—without the slightest reference to, or knowledge of, the structural formation of animal and vegetable cells.

Or that one might succeed as a teacher of the young—might become, even, a nation-wide authority on molding the plastic mind of youth—without ever being assailed by the thought that the forbears of the nimble-minded children in his care, ages and ages ago, may have been swinging from tree to tree by their tails.

And so, in most occupations, it has been contrived for us that we deal only with present-day

facts and conditions—that there is little incentive, aside from general interest or wandering curiosity, to try to lift the veil which obscures our past—or to peer through the fog which keeps us from seeing what to-morrow has in store.

In plant growing, more than in any of the world's other industries, does the scheme of evolution and a working knowledge of nature's methods cease to be a theory—of far-away importance and of no immediate interest—and become an actual working factor, a necessary tool, without which it is impossible to do the day's work.

Whether plant improvement be taken up as a science, as a profession, or as a business—or whether it be considered merely a thing of general interest, an idle hour recreation—there is ever present the need to understand nature's methods and her forces in order to be able to make use of them—to guide them—there always stares us in the face that solitary question:

"Where—and how—did life start?"

We have seen in these books color photographs of corn as it may have grown four thousand years ago, perhaps.

It took less than twelve seasons to carry this plant backward some thousands of years.

How this plant was first taken back to the stage in which it was found by the American Indians, thus revealing the methods which they crudely used to improve it—and how it was taken back beyond the Pharaohs and then back forty centuries before the time of man—how we know these things to be true—and how, as a result of these experiences we are about to see it carried forward by several centuries—all of these things are reserved for a later chapter where space will permit the treatment which the subject deserves.

The illustration is cited here merely as one of thousands, typical of plant improvement, in which, in order to work forward a little, we must think backward ages and ages.

It is cited here to show that what is merely an interesting theory to the mass of the world's workers becomes a definite, practical, working necessity to the man or woman who becomes interested in plant improvement.

It is cited here so that we may be helped to get a clearer mind picture of our viewpoint—of that viewpoint which, after all, has enabled us to become a leader in a new line, the founder of a new art—instead of remaining a nurseryman or gardener.

In my viewpoint there is little that is new—little that has not been discovered by others—

little that has not been accepted by scientists generally—little that requires explanation to those who simply see the same things that I have seen.

I have no new theory of evolution to offer—perhaps only a few details to add to the theories which have already been worked out by men of science.

And I make these observations and conclusions of mine a part of this work for two reasons:

First, because they are products not of imagination, reasoning, or any mental process—but the practical observations and conclusions which have gained force and proof, year by year, in a lifetime of experience with plants—throughout fifty years of continuous devotion to the subject, during which time I have tried more than one hundred thousand separate experiments on plant life; and, as such, represent an important phase of my life.

Second, because an ever-present interest in evolution—an ever-eager mind to peer backward and forward—is essential not only in the practice of plant improvement, but even to the barest understanding of it.

To gain the first quick glimpse, let us liken the process of evolution to a moving picture as it is thrown on the screen.

Imagine, for example, that some all-seeing camera had made a snapshot of nature's progress each hundred years from the time when plant life started in our world to the present day.

Imagine that these progressive snapshots were joined together in a motion picture reel, and thrown in quick succession upon a screen.

We should see, no doubt, as the picture began to move, a tiny living being, a simple cell, the chemical product, perhaps, of warm brackish water—so small that 900 of them would have to be assembled together to make a speck large enough for our human eyes to see.

As snapshot succeeded snapshot we should see that two of these microscopic simple cells in some way or other formed a partnership—probably finding it easier to fight the elements of destruction in alliance than alone.

We should see, beyond doubt, that these partnerships joined other partnerships, and as partnership joined partnership, and group joined group, these amalgamations began to have an object beyond mere defense—that they began to organize for their own improvement, comfort, well-being, or whatever was their guiding object.

We should see that, whereas each simple cell had within it all of the powers necessary to live its life in its own crude way, yet with the amal-

gamation of the cells there came organization, development, improvement.

Some of the cells in each amalgamation, let us say, specialize on seeing, some on locomotion, some on digestion.

Thus, while each simple cell had all of these powers in a limited way, yet the new creature, as a result of specialization, could see better, move more readily, digest more easily, than the separate elements which went into it.

And so, through the early pictures of our reel, there would be spread before us the development of the little simple cell into more and more complex forms of life—first vegetable, then half vegetable-animal—into everything, finally, that lives and grows about us to-day—into us, ourselves.

In an actual motion picture as it is thrown on the screen, it is only the quick progressive succession of the pictures that makes us realize the sense of motion.

If we were to detach and examine a single film from the reel, it would show no movement. It would be as stationary and as fixed as a child's first kodak snapshot.

In the motion picture of nature's evolution, the world, as we see it about us in our lifetime, represents but a single snapshot, detached from

those which have preceded it and from those which are to succeed it.

And so, some of us—too many of us—not confronted with the same necessity which irresistibly leads the plant student into the study of these forces—viewing only the single, apparently unmoving picture before us, have concluded that there is no forward motion—that there has been no evolution—that there will be none.

The plant student, above all others, has the greatest facilities at his hand for observing not only the details of the picture which is now on the screen—but for gaining glimpses—fragmentary glimpses—of pictures which have preceded—of piecing these together—and of realizing that all that we have and are and will be must be a part of this slow, sure, forward-moving change that unfailingly traces itself back to the little simple cell.

As we go further and further into the work we shall begin to see the film fragments which to workers in other lines are obscured, unnoticed, unknown.

We shall be able to observe details of the process—carried home to us with undeniable conviction—indisputable to any man who believes what he actually sees — which will give

us a realistic view of the whole motion picture which to the world at large has always been denied.

We shall find that, dealing thus with nature's forces at first hand, our work will inspire an interest beyond even the interest of creating new forms of life.

And, as our work unfolds, the side lights which we shall see will clear up many or most of the doubts which are likely to take possession of us at the outset.

It may be well at this point, however, to take space to refer to the single question most frequently asked by thousands of intelligent men and women who have been visitors here.

This question, differing in form, as the individualities of the questioners differ, usually runs like this:

"If we are descendants of monkeys, why are not the monkeys turning into men to-day?"

Let us learn the answer to this question by turning to the golden-yellow California poppy, so-called, and the other entirely new poppies which we have produced from it.

In order to make clear the truth which the poppies prove, it is necessary to explain the successive steps of the operation.

A few thousand of the wild golden-yellow poppies such as cover California's hills were examined.

The individuals of these resembled one another as closely as one rose resembles another rose on the same bush, or as one grape resembles another on the same bunch, as one pea resembles another in the same pod.

Yet among those million poppies—all looking alike to the unpracticed eye—there could be found by a close observer nearly as many individual differences as could be found among as many human beings.

Among those million poppies, each with its distinct individuality, one was found which had a slight tendency to break away from the California poppy family and start a separate race of its own.

This same tendency could be observed among a million men, a million roses, a million peas, a million quartz crystals, or a million of any of nature's creations.

Those one, or two, or three out of every million with tendencies to break away are sometimes called the freaks or "sports" of the species.

It seems as though nature, never quite satisfied with her creations, is always experimenting, with the hope of creating a better result—yet

limiting those experiments to such a small percentage that the mass of the race remains unchanged—its characteristics preserved—its general tendencies unaffected.

The California poppy, as it grows wild, is a rich golden yellow. In spite of individual differences, this color is the general characteristic of the kind. It is a fixed characteristic, dating back at least to the time when California, because of the poppy-covered hills, received its name—the land of fire—from the early Spanish navigators that ventured up and down the coast.

Out of the billions of wild poppies that have grown, each million has no doubt contained its freaks or its "sports"—its few experimental individuals which nature has given the tendency to break away from the characteristics of their fellows.

Yet in the history of the California poppy family, as far back as we can trace, none of these freaks or "sports" has ever achieved its object.

Among the "sports" which we found in the million poppies was one with a slight streak of crimson on one petal; one or two with a tendency toward white and one with a lemon-yellow color.

Without the intervention of man, these freaks quite likely would have perished without off-

spring, being submerged by those having the usual fixed tendency.

But by separating them and saving their seeds, within a few brief seasons we were able to produce three new kinds of the California poppy.

Each kind had all of the parent poppy characteristics but one. They were California poppies in habits, growth, shape, form, grace, texture, and beauty.

Yet in color they differed from the California wild poppy almost as a violet differs from a daisy.

One of these freaks developed into a solid crimson poppy, another into the pure white poppy, and still another into the fire-flame poppy —all now well known.

The details of method employed and the application of these methods and the underlying principles to the improvement of other flowers, fruits, trees, and useful and ornamental plants, will be left for later chapters. But, as an illustration, this poppy experiment brings three facts to view.

First, that nature creates no absolute duplicates.

Second, that although each of nature's creations has its own distinctive individuality, all the time she takes special precautions to fix, pre-

WHITE AND CRIMSON SIDE BY SIDE

The poppy still retains many of its wild characteristics, particularly the production of great quantities of seed. Seeds from my experiments have been scattered over the grounds so that poppies are likely to spring up at any point. In this direct-color photograph print the white California poppy and its new crimson cousin are seen growing wild side by side.

serve, and make permanent the characteristics of each of her races or kinds best suited to their environment.

Third, that there is always present in all of her creations the experimental tendency to break away from fixed characteristics—to start new races—to branch out into entirely new forms of development. Through our intervention in the case of the poppy, this tendency was crowned with success; in ten thousand years, perhaps, without intervention, the same result might possibly have occurred.

From the fern at the water's edge to the apple tree which bears us luscious fruit—from the oyster that lies helpless in the bottom of Long Island Sound to the human being who rakes it up and eats it—every different form of life about us may thus be traced to the experiments which nature is continually bringing forth in order to better adapt her creations to their environment.

As to the question so often asked, monkeys are no more turning into men than golden-yellow poppies are turning into crimson, white or fire-flame poppies.

In monkeys, as in men and poppies—and quartz crystals—there is ever present the tendency to break away from the kind, yet nature

is always alert to prevent the break—unless it demonstrates itself to be an advance, an improvement—from occurring.

She gives us, all of us, and everything—individuality, personality—unfailingly, always—at the same time preserving in each the general characteristics of its kind.

Yet all the time she is creating her freaks and "sports"—all the time she is trying new experiments—most of them doomed to die unproductive—with the hope that the dozen freaks among a billion creations may show the way toward a single adaptive improvement in a race.

In this hurried backward glance we have by no means gone back to the beginning of things. Even the moving picture of nature's course from the warm water cell to us, covering what seems an infinity of time, may be but a single stationary film in a still greater moving picture—and that, too, but a part of a greater whole.

Indeed, the further we go into our subject, the more we are convinced that instead of having followed the thread of life to its beginning, we have merely been following a raveling which leads into one of its tiny strands.

The more we learn definitely about the process which we trace back to the simple cell, the more we are led to inquire into those other forms of

energy—into the chemical reactions—into the vibrations which manifest themselves to us as sound, heat, light—into electricity and those manifestations whose discovery is more recent, and whose nature is less well understood.

The more we observe the phenomena in our own fields of activity, the more we realize the futility of trying, in a single lifetime, to explore infinity.

The more content we feel, instead, to learn as much as we can that is useful and practical of the single strand of life's thread which has to do more immediately with the thing in hand.

"What do you put into the soil to make your cannas so fine?"

"How often do you take up the bulbs of your gladioli?"

"How late do you keep your tender plants under glass?"

These, and a hundred others of their kind, are the questions which visitors at the experiment farm are continually asking.

It is not that we do not appreciate the importance of cultivation.

But the questioners fail to realize that our work has been with the *insides* of plants and not with the *externals*.

Of the details of working method—of the little plans that save time—of the bold innovations which many may have dreamed, but none have ever dared to do; of these, in the volumes to come, we shall find plenty.

And we shall find ourselves searching the times when things were not as they are, in order to obtain glimpses of things as they are to be—and all, not from the standpoint of theory, but merely to help us in the very practical, the very useful work of developing by natural methods new forms of plant life—better forms than she would produce for us unaided—plants which because of their greater productivity will help us lower our constantly increasing cost of living—plants which will yield us entirely new substances to be used in manufactures—plants which will grow on what now are waste places—plants which, by their better fruit, or their increased beauty, or their doubled yield, or their improved quality, will add to our individual pleasures and profits and to the pleasure and profits of the whole world.

In order to work forward a little,
we must look backward through
the ages.

THE SHASTA DAISY

How a Troublesome Weed Was Remade Into a Beautiful Flower

HAVING, now, a broad general understanding of the work—of the underlying principles, of the methods involved, and of the possibilities—let us see just how several striking transformations have been accomplished.

There are many of these productions which may be rated as much more important to the world than those described; but these have been selected because they reflect, better than others, the various ways in which methods have been combined to produce final, fixed results; thus serving to give the reader a complete exposition of working detail in the smallest possible space.

We have given, for the first time, the exact steps which we took in producing a number of widely different plant transformations; together with some observations on life—plant, animal, and human.

"White is white," said one of my gardeners, "and all these daisies are white. They all look just the same color to me. No one of them is pure white, but there is one that is nearer white than the rest."

All the other gardeners agreed with the first one, and it was some time before a visitor came who was not of the same opinion. Person after person was questioned, and each one declared that all the daisies in the row seemed to be pure white in color. No one could discriminate between them.

But one day a well known artist visited the garden, and when she was shown the row of daisies and asked about their color, she answered instantly that there was one much whiter than all the rest; and to my own satisfaction she indicated the one that all along had seemed to be whiter than the others. There was no question, then, that this plant bore flowers nearer to purity in whiteness than any others of all the thousands of daisies in the field.

Needless to say that particular plant had been selected for use in future experiments, for the ideal in mind was a daisy that would be of the purest imaginable white in color. How the ideal was achieved—after years of effort—will appear in due course.

The daisies in question, of which the plant bearing the nearly white flowers was the best example, had been produced by several years of experimentation which had commenced with the cultivation of the common roadside weed familiar to everyone in the East as the oxeye daisy, and known to the botanist as *Chrysanthemum leucanthemum*. This plant, which grows in such profusion throughout the East as to be considered a pest by the farmer, was not to be found in California until these experiments were begun.

My admiration for the plant was chiefly as a souvenir of boyhood days. But I soon conceived the idea of bettering it, for it had certain qualities that seemed to suggest undeveloped possibilities.

In the countryside of New England, the oxeye, as everyone knows, is a very hardy plant and a persistent bloomer. Its very abundance has denied it general recognition, yet it is not without its claims to beauty. But it did not greatly improve or very notably change its appearance during the first few seasons of its cultivation in California; nor indeed until after I had given it a new impetus by hybridizing it with an allied species.

THE SHASTA DAISY

The Shasta Daisy (Chrysanthemum hybridum) is probably the most popular flower introduced during the past century. It is grown in all parts of the earth and yields its graceful, snow-white blossoms in abundance with little care or culture. Everybody now knows the Shasta Daisy. It has taken on many interesting new forms of late.

Mating the Oxeyes

The plant with which the cross was made was a much larger and more robust species of daisy imported from Europe, where it is known colloquially as the Michaelmas daisy, although the botanist gives it a distinct name, in recognition of its dissimilar appearance, calling it *Chrysanthemum maximum.* There is also a Continental daisy, by some botanists considered as a distinct species and named *Chrysanthemum lacustre,* which is closely similar to the British species, and of this seeds were secured from a German firm.

Both these plants have larger flowers than the American daisy, but are far inferior to it in grace of form and especially abundance of bloom. The plants have a coarse, weedy appearance, with numerous unsightly leaves upon their flower stalks, whereas the stalk of the American daisy is usually leafless.

Notwithstanding the rather coarse appearance of the European oxeyes, I determined to hybridize them with the American species, in the expectation of producing a plant that would combine the larger flowers of the European with the grace, abundant flowers, and early blooming qualities of the American daisy. The cross was

first made with the English daisy, *C. maximum*, by taking pollen from this flower to fertilize the best specimens of the American daisy that I had hitherto been able to produce.

When the seeds thus produced were sown next season and the plants came to blooming time, it was at once evident that there was marked improvement. Some of the flowers appeared earlier even than those of the American daisy; they were very numerous, and were larger in size than the flowers of either parent. But all the flowers had a yellowish tinge, unnoticed by the average observer, but visible to a sharp eye on close inspection. And this tendency to a greenish yellowness in color was not at all to my liking.

Further improvement was attempted by crossing the hybrid plant with the German daisy just referred to. A slight improvement was noticed, but the changes were not very marked.

By selecting the best specimens of the hybrid, which now had a triple parentage, I had secured, in the course of five or six years, a daisy which was very obviously superior to any one of the original forms as to size and beauty of flower, and fully the equal of any of them in ruggedness and prolific blooming.

But the flowers were still disappointing in that they lacked that quality of crystal whiteness

which was to be one of the chief charms of my ideal daisy. So year by year the rows of daisies were inspected in quest of a plant bearing blooms whiter than the rest; and seeds were selected only from the prize plants.

The daisy spreads constantly, and one clump will, if carefully divided, presently supply a garden. But of course each plant grown from the same plant is precisely like the parent, and while a large number of daisies were secured that combined approximate whiteness with all the other good qualities sought, yet the purest of them all did not appear to be unqualifiedly white.

And when my own judgment was confirmed by the decision of the artist, the determination was made to seek some new method of further improvement that should erase the last trace of offending shade.

As a means to achieve this end, I learned of another, the Asiatic daisy known to the botanist as *Chrysanthemum nipponicum;* and presently obtained the seed of this plant from Japan.

Aid from Japan

This Japanese daisy was in most respects inferior to the original American oxeye with which these experiments had started. It is a

rather coarse plant, with objectionable leafy stalk, and a flower so small and inconspicuous that it would attract little attention and would scarcely be regarded by anyone as a desirable acquisition for the garden. But the flower had one quality that appealed to me—it was pure white.

Needless to say, no time was lost, once these plants were in bloom, in crossing the best of the hybrid daisies with pollen from the flowers of their Japanese cousin.

The first results were not wholly reassuring. But in a subsequent season, among innumerable seedlings from this union, one was found at last with flowers as beautifully white as those of the Japanese, and larger than the largest of those that the hybrid plants had hitherto produced. Moreover the plant on which this flower grew revealed the gracefulness of the American plant, and in due course was shown to have the hardy vigor of all the other species.

From this remarkable plant, with its combined heritage of four ancestral strains from three continents, thousands of seedlings were raised each year for the five or six ensuing seasons, the best individuals being selected and the others destroyed according to my custom, until at last the really wonderful flower that has since become

known to the whole world as the Shasta Daisy was produced.

Moreover I had a flower that excelled my utmost expectations as to size, grace and abundant blooming qualities; a blossom from four to seven inches in diameter, with a greatly increased number of ray flowers of crystal whiteness, and with flower stem tall and devoid of unsightly leaves; a plant at once graceful enough to please the eye and hardy enough to thrive in any soil; a plant moreover of such thrifty growth that it reached its blooming time in its first season from seed, although none of its ancestors bloomed until the second season; and of such quality of prolificness that it continues to bloom almost throughout the year in California, and for a long season even in colder climates.

Conflicting Tendencies

The Shasta Daisy, sprung thus magically—yet not without years of coaxing—from this curiously mixed ancestry, exceeded my utmost expectations in its combination of desirable qualities. I can hardly say, however, that the result achieved was a surprise; for my experience with hundreds of other species had led me to anticipate, at least in a general way, the transformations that might be effected through such

THE SHASTA DAISY AND TWO OF ITS RELATIVES

The upper flower is a form of the Shasta Daisy slightly different from that shown on a preceding page. At the left is shown a newer double form, and at the right its New England parent, all reduced one-half.

a mingling of different ancestral strains as had been brought about.

There was every reason to expect, while hybridizing the American and European ox-eyes, that a plant would ultimately be produced that would combine in various degrees all the qualities of each parent form. By selecting for preservation only those that combined the desirable qualities and destroying those that revealed the undesirable ones, a fixed, persistent hybrid race that very obviously excelled either one of its parent forms was produced.

Nor is there, perhaps, anything very mystifying about this result, for the simpler facts of the hereditary transmission of ancestral traits are now matters of common knowledge and of everyday observation.

No one is surprised for example, to see a child that resembles one parent as to stature, let us say, and the other as to color of hair and eyes.

So a hybrid daisy combining in full measure the best qualities of the European and the American oxeyes, as did my first hybrid race, perhaps does not seem an anomalous product, although certainly not without interest, in view of the fact that its parent stocks are regarded by many botanists as constituting at least two distinct species.

But the final cross, in which the Japanese plant with its small flowers, inferior in everything except lack of color, was brought into the coalition, calls for explanation. A general impression has long prevailed that a hybrid race whether of animals or of plants is likely to be more or less intermediate between the parent races; so perhaps the common expectation would have been that the cross between the new hybrid race of daisies and the obscure Japanese plant would result in a hybrid with medium-sized flowers at best, and, except possibly in the matter of whiteness of blossom, an all round inferiority to the best plants that I had developed.

But, in reality, there appeared the beautiful mammoth Shasta, superlative in all its qualities, surpassing in every respect each and all of the four parent stocks from which it sprang.

This apparently paradoxical result calls for explanation. The explanation is found, so far as we can explain the mysteries of life processes at all, in the fact that by bringing together racial strains differing so widely a result is produced that may be described as a conflict of hereditary tendencies. And out of this conflict comes a great tendency to variation.

The reasons for this are relatively simple. Heredity, after all, may be described as the sum

of past environments. The traits and tendencies that we transmit to our children are traits and tendencies that have been *built into* the organisms of our ancestors through their age-long contact with *varying environmental conditions.*

The American oxeye daisy, through long generations of growth under the specific climatic conditions of New England, had developed certain traits that peculiarly adapted it to life in that region.

Similarly the European daisy had developed a different set of traits under the diverse conditions of soil and climate of Europe.

And in the third place, the Japanese daisy had developed yet more divergent traits under the conditions of life in far away Japan, because these conditions were not only more widely different from the conditions of Europe and America than these are from each other, but also because the Japanese plant came of a race that had in all probability separated from the original parent stock of all the daisies at a time much more remote than the time at which the European and American daisies were separated.

The Plant as a Camera

To make the meaning of this quite clear, we must recall that a given organism—say in this

case a given stock of daisies—is at all times subject to the unceasing influence of the conditions of life in the midst of which it exists. The whole series of influences which we describe as the environment is perpetually stamping its imprint on the organism somewhat as the vibrations of light stamp their influence on a photographic plate.

Indeed, as I conceive it, the plant is in effect a photographic plate which is constantly receiving impressions from the environing world.

And the traits and tendencies of the plant that are developed in response to these impinging forces of the environment are further comparable to the image of the photographic plate in that they have a greater or less degree of permanency according to the length of time during which they were exposed to the image-forming conditions.

If you expose a photographic plate in a moderately dim light, let us say, for the thousandth part of a second, you secure only a very thin and vague negative. But if, without shifting the scene or the focus of the camera, you repeat the exposure again and again, each time for only the thousandth of a second, you will ultimately pile up on the negative a succession of impressions, each like all the rest, that result in the production of a strong, sharp negative.

But if in making the successive exposures, you were to shift the position of the camera each time, changing the scene, you would build up a negative covered with faint images that overlap in such a way as to make a blurred and unmeaning picture.

And so it is with the plant. Each hour of its life there come to it certain chemicals from the soil, certain influences of heat and moisture from the atmosphere, that are in effect vibrations beating on its protoplasmic life substance and making infinitesimal but all-important changes in its intimate structure. The amount of change thus produced in a day or a year, or, under natural conditions, perhaps in a century or in a millennium, would be slight, for the lifetime of races and plants is to be measured not in these small units, but in geological eras.

Nevertheless, the influence of a relatively brief period must make an infinitesimal change, comparable to the thousandth-second exposure of the negative.

And when a plant remains century after century in the same environment, receiving generation after generation the same influences from the soil and atmosphere, the stamp of these influences on its organic structure becomes more and more fixed and the hereditary influence

SHASTA DAISIES—CURIOUS TUBULAR RAY FLOWERS

We have learned through observation of many examples that when a flower or plant once begins to vary, it may continue to vary almost indefinitely. Here is an illustration of a new departure on the part of the Shasta Daisy, in which the petals take on a very curious form. It has interest as a freak rather than because of its beauty, but the variety is worthy of attention, to see what may be its further variation in this direction.

through which these conditions are transmitted to its descendants becomes more and more notable and pronounced.

So it is that a plant that has lived for countless generations in Japan has acquired a profound heredity tending to transmit a particular set of qualities; and when we hybridize that plant with another plant that has similarly gained its hereditary tendencies through agelong residence in Europe, wc bring together two conflicting streams that must fight against each other and strangely disturb the otherwise equable current of hereditary transmission.

Long experience with the hybrids of other species of plants had taught me this, and hence it was that I expected to bring about a notable upheaval in the hereditary traits of my daisies by bringing the pollen of a Japanese plant to the stigmas of my hybrid European and American oxeyes. That my expectations were realized, and more than realized, is matter of record of which the present Shasta Daisy gives most tangible proof.

We shall see the same thing illustrated over and over again in our subsequent studies.

In offering this explanation of the extraordinary conflict of tendencies, with its resulting new and strange combination of qualities that re-

sulted from the mixing of the various strains of daisies, it will be clear that I am assuming that the different ancestral races were all evolutionary products that owed their special traits of stem and leaf and flower to the joint influence of heredity and environment.

I am assuming that there was a time in the remote past when all daisies had a common ancestral stock very different from any existing race of daisies.

Touring the World

The descendants of that ancestral stock spread from the geographical seat of its origin—which may perhaps have been central Asia—in all directions. In the course of uncounted centuries, and along channels that are no longer traceable, the daughter races ultimately made their way to opposite sides of the world. Some now found themselves in Europe, some in America, some in Japan.

Thousands of years had elapsed since the long migration began; yet so persistent is the power of remote heredity that the daisies of Europe and America and Japan even now show numerous traits of resemblance and proof of their common origin that lead the botanist to classify them in the same genus. But, on the other hand, these races show differences of detail as to stem and

leaf and flower and habit which entitle them to rank as different species.

As the likenesses between the different daisies are the tokens of their remote common origin and evidences of the power of heredity, so their specific differences betoken the influences of the different environment in which they have lived since they took divergent courses.

The Japanese daisy is different from the German daisy because the sum total of environment influences to which it has been subjected in the past few thousand years is different from the sum total of influences to which the German daisy has been subjected. Not merely differences due to the soil and climate of Japan and Germany to-day, but cumulative differences due to ancestral environments all along the line of the migration that led one branch of the race of daisies eastward across Asia and the other branch westward across Europe.

Are Acquired Traits Transmitted?

But all this implies that the imprint of the successive environments was in each case an influence transmitted to the offspring; and this is precisely what I mean to imply.

To me it seems quite clear that the observed divergences between the European and the Jap-

anese daisy are to be explained precisely in this way. I know of no other explanation that has any semblance of plausibility.

It is my personal belief that every trait acquired by any organism through the influence of its environment becomes a part of the condition of the organism that tends to reproduce itself through inheritance.

In other words I entertain no doubt that all acquired traits of every kind are transmissible as more or less infinitesimal tendencies to the offspring of the organism.

But it would not do to dismiss the subject without adverting to the fact that there are many biologists who dispute the possibility of the transmission of acquired traits. Indeed, one of the most ardent controversies of recent years has had to do with that point; and doubtless many readers who are not biologists have had their attention called to this controversy and perhaps have received assurance that traits acquired by an individual organism are not transmitted.

I shall not here enter into any details of the controversy, although doubtless we shall have occasion to revert to it. But it is well to clarify the subject in the mind of the reader here at the outset, by pointing out that this controversy, like a good many others, is concerned with unessen-

tial details, sometimes even with the mere juggling of words, rather than with essentials.

As to the broad final analysis of the subject in its remoter bearings, all biologists are agreed.

There is no student of the subject speaking with any authority to-day, who doubts that all animal and vegetable forms have been produced through evolution, and it requires but the slightest consideration of the subject to make it clear that Herbert Spencer was right when he said that no one can be an evolutionist who does not believe that new traits somewhere and somehow acquired can be transmitted.

Otherwise there could be no change whatever in any organism from generation to generation or from age to age: in a word, there would be no evolution.

The point in dispute, then, is not whether any trait and modification of structure, due to the influence of environment, is transmissible, but only as to whether environmental influences that affect the body only and not the germ plasm of the individual are transmissible. But when we reflect that the germ plasm is part and parcel of the organism, it seems fairly clear that this is a distinction without a real difference.

As Professor Coulter has recently said, it is largely a matter of definition.

A BEAUTIFUL LACINIATED TYPE

The flowers shown above, selected from some of my Shasta experiments, have more the appearance of the Chinese chrysanthemum, almost, than of the ordinary Shasta Daisy. It will be noted that the flower at the lower left gives evidence of doubleness to such an extent that the center has become fully double. Notice the laciniated petals.

We shall have occasion to discuss this phase of heredity more fully in another connection. In the meantime, for our present purpose, it suffices to recall that biologists of every school will admit the force of the general statement that heredity is the sum of past environments, and—to make the specific application—that our Japanese and our English and American daisies are different because long generations of their ancestors have lived in different geographical territories and therefore have been subject to diverse environing conditions.

In a word, then, the Shasta Daisy which stands to-day as virtually a new creation, so widely different from any other plant that no botanist would hesitate to describe it as a new species, owes its existence to the bringing together of conflicting hereditary tendencies that epitomize the ancestral experiences gained in widely separated geographical territories.

Without the aid of man, the plants that had found final refuge in Europe and America and Japan, respectively, would never have been brought in contact, and so the combination of traits that built up the Shasta Daisy would never have been produced.

In that sense, then, artificial selection created the Shasta Daisy, but the forces evoked were

those that nature provided, and the entire course of my experiments might be likened to an abbreviated transcript of the processes of natural selection through which species everywhere have been created, and are to-day still being created, in the world at large.

New Races of Shastas

Once the divergent traits of these various strains had been intermingled, the conflict set up was sure to persist generation after generation.

Each individual hereditary trait, even though suppressed in a single generation by the prepotency of some opposing trait, strives for a hearing and tends to reappear in some subsequent generation.

So the plant developer, by keenly scrutinising each seedling, will observe that no two plants of his hybrid crop are absolutely identical; and by selecting and cultivating one divergent strain or another, he may bring to the surface and further develop traits that had long been subordinated.

Seizing on these, I was enabled, in the course of ensuing years, to develop various races of the Shasta, some of which were so very different that they have been given individual names. The Alaska, for example, has even larger and more numerous blossoms than the original Shasta,

with longer and stronger stems and more vigorous and hardy growth. The Westralia has blossoms of even greater size, and exceptionally long, strong, and graceful stems, and the California has a slightly smaller flower, but produced in great profusion; and its blossoms, instead of being snowy white like those of the other races, are bright lemon yellow on first opening.

Moreover the enhanced vitality due to cross-breeding and the mingling of different ancestral strains, was evidenced presently in a tendency to the production not merely of large blossoms, but of blossoms having an increased number of ray flowers.

The daisy is a composite flower, and the petal-like leaves that give it chief beauty are not really petals, but are technically spoken of as rays. The flowers proper, individually small and inconspicuous, are grouped at the center of the circling rays.

In all the original species the ray flowers constitute a single row. But the hybrids began almost from the first to show an increased number of longer and wider ray flowers, some of which overlapped their neighbors.

By sowing seed from flowers showing this tendency, after a few generations a strain of plants was developed in which the blossoms were

characterized by two rows of ray flowers instead of one. Continuing the selection, flowers were secured in successive generations having still wider and longer rays and increased numbers of rows, until finally handsome double-flowered varieties were produced.

Aberrant forms were also produced showing long tubular ray flowers and others having the rays fimbriated or divided at the tip.

And all these divergent and seemingly different types of flowers, it will be understood, have the same remote ancestry, and represent the bringing to the surface—the segregation and recombination and intensification—of diverse sets of ancestral traits that had long been submerged.

It is certain that no plant precisely like the Shasta Daisy or any one of its varieties ever existed until developed here in my gardens at Santa Rosa.

I have never entertained a doubt as to the transmissibility of acquired characters and tendencies.

THE WHITE BLACKBERRY

How a Color Transformation was Brought About

TO SPEAK of white blackbirds or of white blackberries is to employ an obvious contradiction of terms. Yet we all know that now and again a blackbird does appear that is pure white. And visitors to my experiment gardens during the past twenty years can testify that the white blackberry is something more than an occasional product—that it is, in short, a fully established and highly productive variety of fruit.

There is no record of anyone having ever seen a truly *white* blackberry until this anomalous fruit was produced.

Nevertheless it should be explained at the outset that the berry with the aid of which I developed the new fruit was called a white blackberry. It was a berry found growing wild in New Jersey, and introduced as a garden novelty, with no pretense to value as a table fruit, by Mr. T. J. Lovett. He called the berry "Crystal

White," but this was very obviously a misnomer as the fruit itself was never white, but of a dull brownish yellow. It has as little pretension to beauty as to size or excellence of flavor, and was introduced simply as a curiosity.

When a white blackbird appears in a flock, it is usually a pure albino. It may perhaps be regarded as a pathological specimen, in which, for some unknown reason, the pigment that normally colors the feathers of birds is altogether lacking.

It is not unlikely that the original so-called white blackberry was also an albino of this pathological type. But if so, hybridization had produced a mongrel race before the plant was discovered by man, or at least before any record was made of its discovery; for, as just noted, the berry introduced by Mr. Lovett could be termed white only by courtesy.

Nevertheless the berry differed very markedly from the normal blackberry, which, as everyone knows, is of a glossy blackness when ripe. So my interest in the anomalous fruit was at once aroused, and I sent for some specimens for experimental purposes soon after its introduction, believing that it might offer possibilities of improvement.

Making use of the principles I have found successful with other plants, my first thought was to

hybridize the brownish white berry with some allied species in order to bring out the tendency to variation and thus afford material for selective breeding.

Creating a Really White Blackberry

The first cross effected was with the Lawton blackberry, using pollen from the Lawton berry. The Lawton is known to be very prepotent; it is of a very fixed race and will reproduce itself from seed almost exactly, which is not true of most cultivated fruits. Its seedlings often seem uninfluenced when grown from seed pollinated by other varieties.

It was to be expected, therefore, that the cross between the Lawton and the "white" berry would result in producing all black stock closely resembling the Lawton; and such was indeed the result.

But the Lawton also imparts its good qualities to hybrids when its pollen is used to fertilize the flowers of other varieties. As a general rule, it is my experience that it makes no difference which way a cross is effected between two species of plants. The pollen conveys the hereditary tendencies actively, and so-called reciprocal crosses usually produce seedlings of the same character.

That is to say, it usually seems to make no practical difference whether you take pollen from flower A to fertilize flower B, or pollen from flower B to fertilize flower A.

This observation, which was first made by the early hybridizers of plants more than a century ago—notably by Kölreuter and by Von Gærtner—is fully confirmed by my own observations on many hundreds of species. Nevertheless, it occasionally happens that the plant experimenter gains some advantage by using one cross rather than the other. In the present case it seemed that by using the Lawton as the pollenizing flower, and growing berries on the brownish white species, a race was produced with a more pronounced tendency to vary.

Still the plants that grew from seed thus produced bore only black berries in the first generation, just as when the cross was made the other way. It thus appeared that the prepotency of the Lawton manifested itself with full force and certainty whether it was used as the staminate or as the pistillate flower.

When the flowers of this first filial generation were interbred, however, the seed thus produced proved its mixed heritage by growing into some very strange forms of vine. One of these was a blackberry that bloomed and fruited all the year.

This individual bush, instead of dying down like others, kept growing at the top like a vine or tree, and when it was two or three years old it was so tall that a stepladder was required to reach the fruit. Its berries, however, were rather small, soft, and jet black in color.

This plant, then, was an interesting anomaly, but it gave no aid in the quest of a white blackberry.

But there were other vines of this second filial generation—grandchildren of the Lawton and the original "Crystal White"—that showed a tendency to vary in the color of their fruit, this being in some cases yellowish white. Of course these bushes were selected for further experiment. Some were cross-fertilized and the seed preserved.

The vines that grew from this seed in the next season gave early indications of possessing varied qualities. It is often to be observed that a vine which will ultimately produce berries of a light color lacks pigment in its stem, and is greenish or amber in color, whereas the stem of a vine that is to produce black berries is dark brown or purple. A few of the blackberry vines of the third generation showed this light color; and in due course, when they came to the fruiting age, they put forth heavy crops of clear white berries of such

THE CRYSTAL WHITE SO CALLED

Some thirty years ago we learned that a wild blackberry of New Jersey pictured opposite, lighter in color than any other blackberry, had been introduced as a garden novelty under the name Crystal White. Although lighter than any other blackberry, it was of a muddy brown color, as can be seen from the photograph. The berries were small and of poor flavor. This wild berry, however, was the first step in the production of the new varieties of the true white blackberries.

transparency that the seeds, though unusually small, could readily be seen through the translucent pulp.

These were doubtless the first truly white blackberries of which there is any record. But there were only four or five bushes bearing these white berries in an entire generation comprising several hundred individual bushes, all having precisely the same ancestry.

From among the four or five bushes the one showing a combination of the best qualities was selected and multiplied, until its descendants constituted a race of white blackberries that breeds absolutely true as regards the white fruit.

Now Breeds True from Seed

The descendants of this particular bush were widely scattered and passed out of my control. But subsequently, from the same stock, I developed other races, and finally perfected, merely by selection and interbreeding from this same stock, a race of white blackberries that breeds true from the seed, showing no tendency whatever to revert to the black grandparental type.

This is, in short, a fruit which if found in the state of nature would unhesitatingly be pronounced a distinct species. Its fruit is not only snowy white in color, but large and luscious, com-

parable in the latter respect to the Lawton berry which was one of its ancestors.

"Was there ever in nature a berry just like this?" a visitor asked me.

Probably not; but there was a small white berry and a large luscious black one, and I have brought the best qualities of each together in a new combination.

The Anomaly Explained

Reviewing briefly the history just outlined, it appears that the new white blackberry had for grandparents a large and luscious jet black berry known as the Lawton blackberry and a small ill-flavored fruit of a yellowish brown color. The descendant has inherited the size and lusciousness of its black ancestor, and this seems not altogether anomalous. But how shall we account for the fact that it is pure white in color, whereas its alleged white ancestor was not really white at all?

The attempt to answer that question brings us face to face with some of the most curious facts and theories of heredity. We are bound to account for the white blackberry in accordance with the laws of heredity, yet at first blush its dazzling whiteness seems to bid defiance to these laws, for we can show no recognized white ancestor in explanation.

This whole matter is so simple, however, that anyone can see the cause of this unusual whiteness. All plant breeders realize that any quality can be intensified to almost any extent by careful and persistent selection.

There is, of course, no other very plausible explanation available of the origin of the anomalous berry. White is not a favorite color either among animals or among vegetables. Except in Arctic regions it is very rare indeed to find an unpigmented animal or bird, and white fruits are almost equally unusual.

In the case of animals and birds, it is not difficult to explain the avoidance of white furs and feathers. A white bird, for example, is obviously very conspicuous, and thus is much more open to the attacks of its enemies than a bird of some color that blends with its surroundings. So we find that there is no small bird of the Northern Hemisphere, with the single exception of the snow bunting, which normally dresses wholly in white. The exception in the case of the snow bunting is obviously explained by the habits of the bird itself.

And even this bird assumes a brownish coat in the summer.

There are a few large waterfowl, notably the pelican and certain herons that wear snowy white

plumage habitually throughout the year. But these are birds of predacious habits that are little subject to the attacks of enemies, and it has been shown that the white color, or bluish white, tends to make the birds inconspicuous from the viewpoint of the fish that are their prey.

So in the case of the tiny snow bunting and of pelicans and herons, the white color of the plumage is seen to be advantageous to its wearer and hence is easily explained according to the principle of natural selection. The same is true of the white plumage assumed by those species of grouse and ptarmigan that winter in the Arctic or sub-Arctic regions; and contrariwise, the pigmented coats of the vast majority of the birds and animals of temperate zones are accounted for on the same principle.

But just why the fruits of plants should almost universally be pigmented seems at first not quite so clear. It is ordinarily supposed to be advantageous for a plant to have its fruit made visible to the birds and animals, that the aid of these creatures may be gained in disseminating the seed. And it must be obvious that a white blackberry would be as conspicuous in the woodlands where this vine grows as are the jet black berries of the ordinary type.

Why, then, you ask, has not natural selection developed a race of white blackberries?

I am not sure that anyone can give an adequate answer. Perhaps it is desirable to have the seeds of a plant protected from the rays of the sun, particularly from those ultra-violet rays which are known to have great power in producing chemical changes. Recent studies of the short waves of light beyond the violet end of the spectrum show that they have strong germicidal power.

It will be recalled that the celebrated Danish physician Dr. Finsen developed a treatment of local tubercular affections based on the principle that ultra-violet light destroys the disease germs. And most readers have heard of Dr. Woodward's theory that very bright light is detrimental to all living organisms.

Possibly too much sunlight might have a deleterious effect on the seeds of such a plant as the blackberry. Indeed, the fact that the berry quickly develops pigments under ordinary conditions, and develops them much earlier than the stage at which it is desirable to have the fruit eaten by birds, suggests that this pigment is protective to the fruit itself in addition to its function of making the fruit attractive to the bird.

But be the explanation what it may, the fact remains that very few fruits in a state of nature are white; and no one needs to be told that fruits of the many tribes of blackberries, with the single exception of the one under present discussion, are of a color fully to justify the name they bear. Yet the experiment in breeding just recorded proves that, at least under the conditions of artificial selection, a race of berries may be developed which, though having the flavor and contour of the blackberry, is as far as possible from black in color.

The fact that this race of white berries was developed in the third generation from parents one of which is a jet black fruit and the other a fruit of a brownish tint, seems at first glance to give challenge to the laws of heredity.

Atavism and Unit Characters

Even though we should assume that a remote ancestor of our newly developed white blackberry might have been a pure albino, the case still seems mysterious. Cases of reversion to the type of a remote ancestor have been observed from time to time by all breeders of animals and by students of human heredity, and it has been customary to explain such cases of reversion, or at least to label them with the word "atavism."

If this word be taken to imply that all traits and tendencies of an ancestral strain are carried forward from generation to generation by heredity, even though unable to make themselves manifest for many generations, and that then, through some unexplained combination of tendencies, the submerged trait is enabled to come to the surface and make itself manifest, the explanation must be admitted to have a certain measure of tangibility.

Nevertheless, there is a degree of vagueness about the use of the word "tendencies" that robs the explanation of complete satisfactoriness.

Meantime the human mind is always groping after tangible explanations of observed phenomena. It is always more satisfactory to be able to visualize processes of nature. It was for this reason that Darwin's theory that natural selection is the most powerful moving factor in the evolution of races gained such general recognition and still remains as the most satisfactory of all hypotheses of evolution.

And it is for the same reason that a tangible explanation of the phenomena of atavism or the reversion to ancestral types has gained a tremendous vogue in recent years.

The explanation in question is associated with the name of the Austrian monk Mendel, who

SIGNS OF SUCCESS—LARGER YELLOW-WHITE BERRIES

From among many crosses between the Lawton and the old Crystal White a berry very much improved in size was secured, as shown on the opposite page, and the form, texture, and flavor were brought up to the point which made it almost worth growing for its fruit, while the color, though still far from white, was much lighter than even that of the wild Crystal White. This variety was a first generation cross with the Lawton, a blackberry, and was raised from Lawton seeds.

made some remarkable experiments in plant breeding about half a century ago, and who died in 1884, but whose work remained quite unknown until his obscure publications were rediscovered by Professor Hugo de Vries and two other contemporary workers, and made known to the world about the year 1900. Since then a very large part of the attention of the biological world has been devoted to the further examination of what has come to be spoken of as Mendelian principles.

And, as is usual in such cases, unwarranted expectations have been aroused in some quarters as to the real import and meaning of the new point of view; also a good deal of misunderstanding as to the application of the so-called Mendelian laws of heredity to the work of the practical plant developer.

In view of the latter fact it is well to bear in mind that such experiments in plant breeding as those through which I developed the white blackberry and hundreds of others were made long before anything was known of Mendel and his experiments, and at a time when the conceptions now associated with Mendelism were absolutely unknown to any person in the world. It is well to emphasize this fact for two reasons: first, as showing that practical breeding, resulting in the

bringing to the surface of latent traits—for example, whiteness in the blackberry—could be carried to a sure and rapid culmination without the remotest possibility of guidance from "Mendelism;" secondly, because from this very fact the interpretation of my experiments has fuller significance in its bearing on the truth of the Mendelian formulas than if the experiments had been made with these formulas in mind.

This is true not alone of the creation of the white blackberry, but of the similar development of the Shasta Daisy and of a host of other new forms of plant life that will find record in successive chapters of the present work.

But while I would thus guard the reader against the mistake, which some enthusiasts have made, of assuming that the Mendelian formula about which so much is heard nowadays must revolutionize the methods and results of the plant breeder, I would be foremost to admit that the remarkable work of Mendel himself, together with the work of his numerous followers of the past ten years, has supplied us at once with several convenient new terms and with a tangible explanation or interpretation of a good many facts of plant and animal heredity that heretofore have been but vaguely explicable, even though clearly known and demonstrated as facts.

A knowledge of Mendelism may be called the A B C of plant breeding, and when it was first advocated in America at the International Plant Breeding Conference in New York, October 2, 1902, it was generally thought by those who had little or no knowledge of the results of experimental evolution that those who had been producing plants and animals of superlative value were far behind the times and would immediately be outdistanced by those who adopted the new theory in experimenting—in fact, the practical and eminently successful breeders were looked upon by many of those who were enthusiastically advocating the new theory as blind workers. Many of these theoretical breeders who were more or less without much practical experience or knowledge of the results of a careful experimental study of heredity, variation, hybridization, etc., made many public statements of what they had planned and were about to do to secure immediate important practical results. Many of those connected with the experiment stations and others were much carried away, and promised to accomplish things at which the experienced breeders could only smile until the awakening to the fact that nature's ways were somewhat more complicated than they had been led to believe.

A paintbrush and a pot of paint never made an artist unless there was something more than theory for a guide. Extensive plant breeding requires for its success a very broad and extensive knowledge of botany, biology, evolution, physiology, chemistry, paleontology, and of the whole life history of the earth and its plants, a good knowledge of heredity, environment, variation, adaptation, germination, inheritance, expression, adjustment, elimination, and of hardiness, plant diseases and how to eliminate them, insects and how to overcome them, of soils, of the practical changes to be made and how to attain them, with a knowledge of foods, flavors, fragrance, colors; the requirements of markets, shippers, dealers, and consumers; in fact, a broad and comprehensive general knowledge of the work of those who have gone before, and a technique in the work which can never be acquired except by most constant and careful study of the living, growing plants themselves, and a fund of patience with this most enticing game with nature which knows no end.

The case of the white blackberry with which we are at the moment concerned, is a very good illustration in point.

My experiments in the development of that berry might be interpreted in the older terminol-

ogy something like this: The big, luscious, black Lawton blackberry proved prepotent when crossed with the small brownish "Crystal White," and the offspring were therefore all large luscious black berries closely similar to the prepotent parent. But the qualities of the other parent were latent in these offspring, and—the tendency to variation having been stimulated by the hybridizing of these different forms—the offspring of the second generation showed great diversity, and a tendency to reversion to the traits of the more obscure or less prepotent of the two grandparents.

In the still later generations, the conflict of hereditary tendencies continuing, an even more striking reversion, according to the principle of atavism, took place in the case of a few of the many progeny, bringing to light the pure white berry, a heritage from its brownish ancestor.

The Mendelian Explanation

Now this, as I say, would fairly explain the case of the white blackberry in such terms as were universally employed at the time when this interesting fruit was developed.

But the evolutionist of to-day, considering the same facts, would be likely to offer an explanation in Mendelian terms that would have the

merit of adding a certain measure of tangibility to the mental picture of the actual processes involved in the hereditary transmission of traits through which the white blackberry was developed. And there can be no question of the convenience of these terms and of their value in aiding to conjure up such a picture, provided it be not supposed that the presentation of such a formula is to clarify all the mysteries of heredity and to do away with the necessity in the future—as some misguided enthusiasts have assumed—of laborious and patient experiments akin to those through which the triumphs of the plant developer have been achieved in the past.

In a word, the Mendelian formulas, if accepted at their true valuation and for their real purpose, may be regarded as placing new and valuable tools in the hands of the plant experimenter, just as did the formula of natural selection as put forward by Darwin; but we must in one case as in the other guard against imagining that the phrasing of a formula may properly take the place of the practical observation of matters of fact.

Bearing this caution in mind, let us note the changed terminology in which the Mendelian of to-day interprets the observed facts of the de-

velopment of the white blackberry. His explanation would run something like this:

When the Lawton blackberry is crossed with the whitish berry, all the offspring of the first filial generation are black because blackness and whiteness are a pair of "unit characters," both elements or factors of which cannot be manifested in the same individual; and blackness is the "dominant" character of the two, whiteness being "recessive."

But the hereditary factors or "determiners" that make for whiteness, though momentarily subordinated, are not eliminated, and half the germ cells produced by the hybrid generation in which blackness is dominant, will contain the factor of whiteness, whereas the other half contain the factor of blackness. And when in a successive generation a germ cell containing the factor of whiteness unites with the germ cell of another plant similarly containing the factor of whiteness, the offspring of that union will be white, their organisms inheriting no factor of blackness whatever.

It may chance, however, that for many successive generations a germ cell containing only the factor of whitness fails to mate with another similar germ cell and so no white-fruited progeny is produced. In such a case for generation

WHITE BLACKBERRIES AS THEY GROW

The direct-color photograpn print opposite gives evidence that the improved white blackberries were not only selected for color, flavor, size, firmness, and the season of bearing, but also for the form, hardiness, and other good qualities of the plant that bears them. In the final production of any new fruit, all of these qualities and many others must enter into consideration — and a perfect balance or combination of all of them is the triumph of final selection.

after generation the white factors continue to be produced in the germ cells, but the union with a germ cell containing the black factor obscures the result just as in the case of the first cross, because the factor of blackness continues to be dominant.

But, however long delayed, when a cell containing the white factor or determiner does mate with a similar cell, the offspring is white and—in the older terminology—reversion or "atavism" is manifested.

A very simple and tangible illustration of the phenomena in question is furnished by the experiments in animal breeding made by Professor William E. Castle of Harvard. These experiments furnish a peculiarly appropriate illustration in the present connection because it chances that the animals experimented with are comparable to our blackberries in that they are respectively black and white in color.

The animals used in the experiment are guinea pigs.

An Illustration from the Animal World

Professor Castle shows that if a black guinea pig of a pure strain is mated with a white guinea pig of a pure strain, all the offspring of the first generation will be black; and it is therefore said that blackness is preponent or dominant, and

whiteness recessive. But if two of these black offspring are interbred, it is an observed fact that among their progeny three out of four individuals will be black like their parents and one of their grandparents, and the fourth one will be white like the other grandparent.

The Mendelian explains that the factor of whiteness was submerged, dominated by the factor of blackness, in the second generation; but that half the germ cells of these black individuals contained the factor of whiteness, and that by the mere law of chance the union of these germ cells brought together about one time in four two of the cells having the recessive white factor; such union resulted in a white individual.

Meantime by the same law of chance the other three matings out of the four brought together in one case two black factors and in two cases a mixture of black and white factors.

As black is dominant, these individuals having the mixed factors would be individually black (just as those of the first cross were black); but their progeny in due course will repeat the formula of their parent by producing one white individual in four.

It should be explained that the Mendelian, in expressing this formula, usually substitutes for the word "factor," as here employed, the newly

devised word "allelomorph," although the less repellant equivalent "determiner" is gaining in popularity. He calls the body substance of an animal or plant a "zygote," and he describes an individual that contains factors of a single kind, as regards any pair of unit characters (say only for blackness in the case of our blackberries or Professor Castle's guinea pigs), as a "homozygote"; contrariwise a body having both types of factors (blackberries or guinea pigs of the second generation, for example) as a "heterozygote."

But these big words, while it is convenient to know their meaning, need not greatly concern us. It suffices to recall the convenient terms "dominant" and "recessive"; to recognize that a good many antagonistic traits may be classed as unit characters; and to welcome the conception of the division of the factors or determiners of such a pair of unit characters in the germ cell, as enabling us to form a tangible picture of the *modus operandi* through which the observed phenomena of heredity may be brought about.

Mixed Heritage of the Blackberries

It remains to be said that the case of our blackberries is a little more complex than the case of the guinea pigs just referred to, because there

is a second pigment involved. The "Crystal White" berry, it will be recalled, was not white but brownish in color. There were thus transmissible two pairs of unit characters involved as regards the matter of color, namely (1) black versus white, and (2) yellow or brown versus white.

The black factor or determiner dominated absolutely in the first generation; but in the second generation a certain number of germ cells were paired in such a way as to eliminate the black but retain the yellow factor.

It required a third mixture of the germ-cell factors to produce a union in which neither black nor yellow factors appeared, the offspring of this union being of course the pure white blackberry.

The presence of the yellow factor accounts for the further fact, to which reference should be made, that there were various intermediate types of berries, neither black nor white, which appeared in successive generations but which are eliminated by selection as they did not fall in with our plan of development of a white race.

The explanation just given makes it clear that, once a union of germ-cell factors having only the white element was effected, the black and the yellow factors being entirely eliminated from that particular individual, the germ cells arising from that individual would necessarily

contain only the factor of whiteness; hence that all the progeny of that individual would breed true and produce white berries.

Such is indeed the observed fact with my developed strains of white blackberries. Grown from the seeds, these breed far truer to their parentage than is the case with most cultivated fruits. As to certain other qualities they may vary, but all are white.

The Mendelian explanation obviously cannot add any force to this observed and long ago recorded fact.

But it does serve to explain the observed fixity and permanency of the new and anomalous breed. It enables us in a sense to *understand* the paradoxical fact that a berry having a whole galaxy of black ancestors may have no strain of blackness, no tendency to reversion to the black type, in its composition.

But we must not put the cart before the horse by supposing that the new explanation adds anything to the force of the previously observed facts. Hypotheses are for the interpretation of observed phenomena, not phenomena for the interpretation of hypotheses.

One other word in this connection. To would-be plant experimenters who ask my opinion of matters connected with the old versus the new

interpretations of heredity, I am accustomed to say:

"Read Darwin first, and gain a full comprehension of the meaning of Natural Selection. Then read the modern Mendelists in detail. But then—go back again to Darwin."

Bear in mind Professor J. M. Coulter's comment that "Mendelism has extended from its simple original statement into a speculative philosophy," and try for your own satisfaction to separate the usable formulæ from the intricate vagaries of the new creed of heredity.

Let me cite a recent assertion of Professor William E. Castle, himself one of the foremost experimenters along the lines of the newest theory:

"As to how a new race is begotten we have not got much beyond Darwin; indeed many of us have not got so far."

The man who has got as far as Darwin in the matter of understanding racial origins—to say nothing of getting beyond him—even in our day, is no tyro in the study of heredity.

Read Darwin first; then read the modern Mendelists; and then—go back to Darwin.